Gas Journal

VOL. 297. 111th YEAR. LONDON, FEBRUARY 18, 1959 No 4988 PRICE 1/6

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MAR 13 1959
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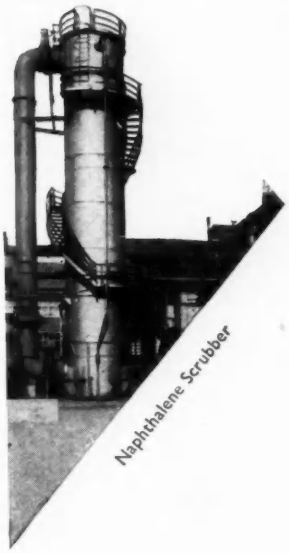
gas and chemical engineering plant

HOLMES

dust collection and control plant

Benzole Recovery and Desulphurising Plant



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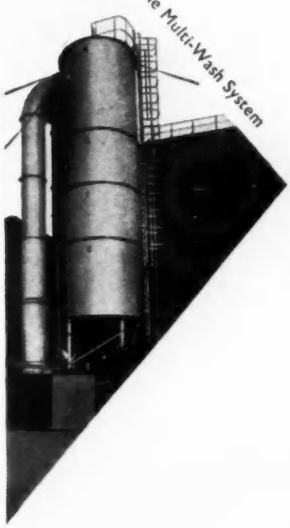
Holmes-Schneible Multi-Wash System



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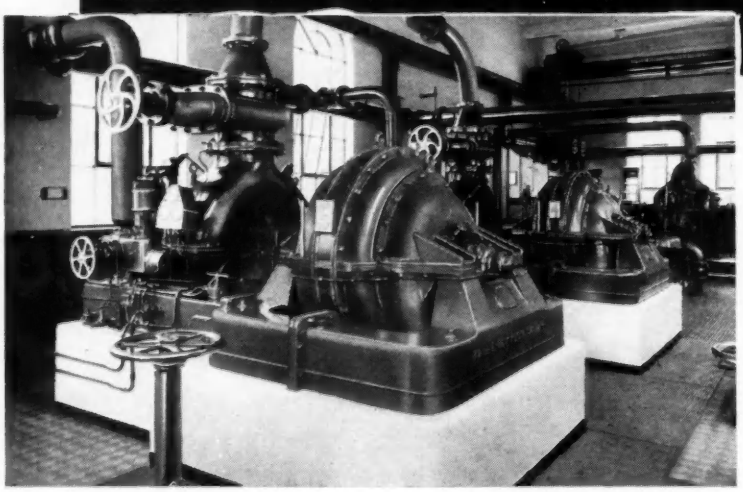

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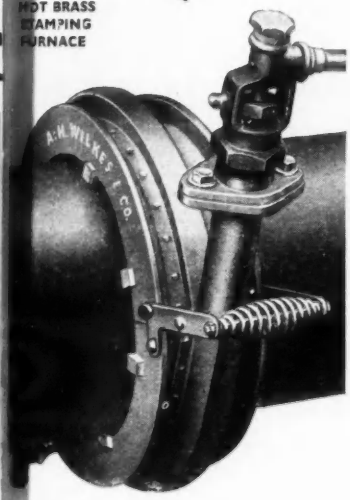

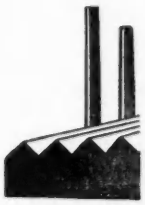

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Gas Journal

VOL. 297 NO. 4988 FEBRUARY 18, 1959

111TH YEAR

MANAGING DIRECTOR: Clifford A. King

EDITOR: Geoffrey W. Battison

ASSISTANT EDITOR: Colin J. Godbold

TECHNICAL EDITOR: Charles J. P. de Winton, T.D., M.A., M. Inst. Gas E., M. Inst F.

Published by Walter King Limited,
11, Bolt Court, Fleet St., London, E.C.4
Telephone: FLEet Street 2236-7 Telegrams:- Gasking, Fleet.

CONTENTS

EDITORIAL COMMENT

That Elusive Fuel Policy - 273
Sludge Gas - 274
Translators Beware! - 274

CORRESPONDENCE

Safer than Electricity. From 'F. H.' - 275

SPECIAL ARTICLE

Underground Storage in France. By Maurice Moval - 278

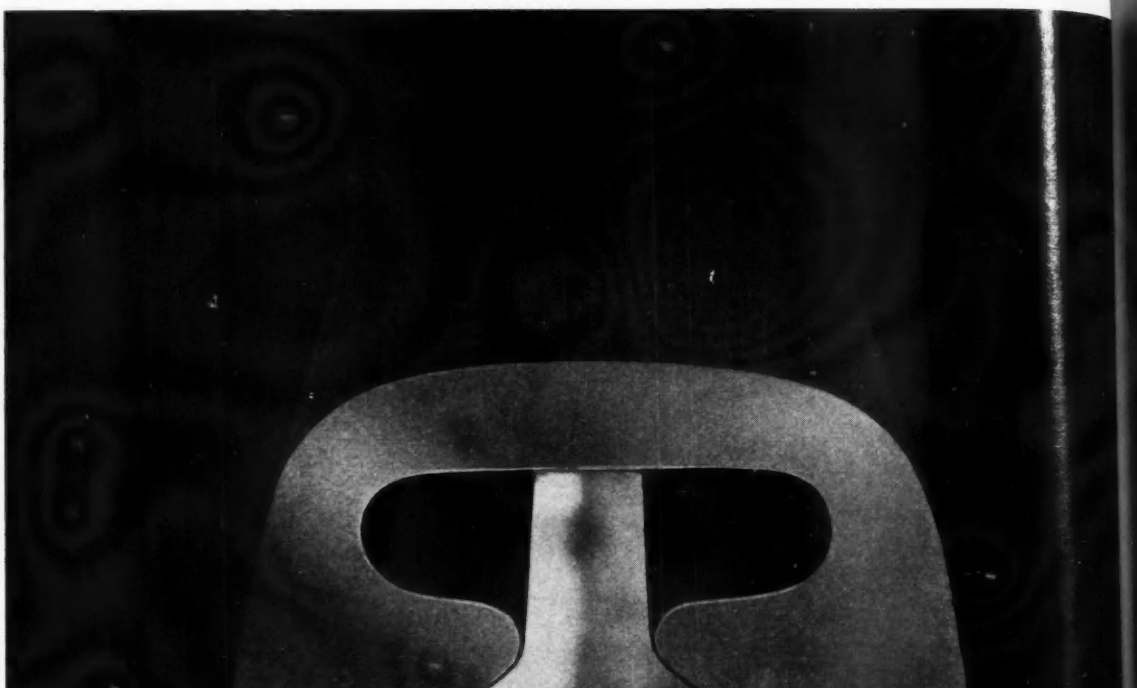
NEWS OF CURRENT EVENTS

Personal - 275
Obituary - 275
Diary - 275
Work Study Symposium for Midland Section - 276
Films and Models on Loan - 276
Parents See Their Sons at Work - 276
Power-Gas Add to Employee Amenities - 276
Pipe-line for Coal Used in Ohio - 276
Powers-Samas and B.T.M. Combine - 276
Smoke Control Quiz for Local Authorities - 277
Juniors Saturday Events Attract Big 'Gates' - 277
Gasworks Profit Ridiculous - 281
Introducing Three New Cookers - 282

TECHNICAL RECORD

Combustion Noise. By J. K. Kilham and T. J. B. Smith - 284
Odour and Odorisation of Gas. By K. A. Deadman and J. A. Prigg - 288

PUBLISHERS' NOTICE, See Page 249, February 11, 1959



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Gas Journal

VOLUME 297. No. 4988 FEBRUARY 18, 1959. 111th YEAR

That Elusive Fuel Policy

LIKE world peace and a lower cost of living, a national fuel policy has joined the list of desirable things which everybody expects but which never materialise. In general, the policy of the present Government, in so far as it has one in this connection, seems to be to let well alone and allow the various fuels to find their own level. One result of this is the unhappy state in which the Coal Board now finds itself, and it is a little ironical to note that a number of people who were in the forefront of any attack on the N.C.B. a few years ago, are now springing to its defence. Indeed, there are signs of a distinct 'back to coal' movement, and they were clearly discernible in the House of Commons debate on the need for a national fuel and power policy a week or so ago.

The debate was on a motion moved by Mr. W. Blyton (Lab., Houghton-le-Spring): 'That this House, having regard to the present serious fall in the demand for coal in this country, the high level of coal stocks, and the decline in coal exports, calls upon Her Majesty's Government to frame as a matter of urgency a policy for the fuel and power industries of this country to secure a proper balance in the use of imported and indigenous fuel and the effective co-ordination of the three nationalised fuel industries—coal, gas and electricity—and to present proposals to this House to that end.' Maintaining that the Government seems to have 'declared war on coal' and that the coal industry was again to be the 'whipping boy of this free-for-all economy' because 'oil has been given the green light,' Mr. Blyton criticised the Gas Council for including only £300,000 of their £670,000 research budget on work associated with the gasification of coal.

Mr. George Darling (Lab., Hillborough) also thought there was a slackening off of the Gas Council's research into the use of coal carbonisation projects and that this was a retrograde step.

'If we go on with carbonisation and gasification programmes,' he said, 'obviously we shall have more gas. Therefore, this coal research must be associated with the appliances which will use the derivatives of coal. We need a gas grid into which gas can be pumped under pressure all over the country, and that means that many industries will have to switch over their appliances. Research workers might look into what can be done by changing over to gas-fired furnaces instead of oil and coal-fired furnaces.'

It was Mr. Gerald Nabarro (Con., Kidderminster) who pointed out that the increased use of oil was not confined to the nationalised industries and that the reason was because oil was 'so clean, so flexible, so highly efficient, so easily controlled and so relatively stable in price.' And he moved an amendment endorsing the Government's policy.

We often think that the remarks made by Mr. Emanuel Shinwell (Lab., Easington) today are considerably more interesting than those he made during his term as Minister of Fuel and Power. Certainly there is none of the exultation of his 'lock, stock and barrel' days, but there is instead a good deal of common sense based on long experience and a fundamentally honest approach to the subject. On this occasion it was he who pointed out the basic fact that there is a great shortage of gas coal and there will be a greater shortage in the future. It was necessary to have a balanced fuel and power policy, he said. 'We must co-ordinate the coal, gas and electricity industries. I say that we must integrate. It was our intention years ago to do that, when we talked about fuel and power. The intention was not merely to take over the coal, electricity and gas industries and allow them to stand on their own heads or hang by their own tails.' Which we suppose is hardly the same as letting them stand on their own feet!

The oddest remarks in the debate (in which the motion was defeated and Mr. Nabarro's amendment approved) came from Sir Albert Braithwaite (Con., Harrow West). 'It should not be forgotten,' he said, 'that we have another menace coming along. There is a 30,000-ton

vessel on the way from America carrying compressed gas which amounts to the equivalent of 12,000 tons of coal. I have just returned from the United States and I understand that 30 other ships are to be built to further the sale of compressed gas all over the world. If we allow that gas to come here, and destroy our carbonising industry, it may be not 14,000 but 40,000 miners who will be out of work, and that will be a very serious matter for this country.'

Sir Albert did not say what he thought the gas industry should do instead of trying to find a cheaper therm, but fortunately Sir Ian Horobin, Parliamentary Secretary to the Ministry of Power, put the matter in a nutshell. 'The gas industry, which finds that it can hold its own in competitive conditions and keep down the price of gas by using tail gas or imported methane, is part of the nation and, as such, plays a part in the determination of a national fuel policy,' he said. 'That is the only way in which the nation can decide upon a policy, in fact. The general principle which the Government commend to the Honse is that the final person who must decide is the consumer and that the only way of discovering what is a national fuel policy is to give the nation the opportunity to say what it wants.'

Much the same thing was said by Lord Mills in his clash with Mr. Ernest Jones, the President of the National Union of Mineworkers, at the quarterly meeting of the National Production Advisory Council on Industry. He maintained that the Government should not interfere in the choice of fuels and their use by industry, while Mr. Jones did not think it was sound economic policy for the Government to allow the consumer to use any fuels he wished.

Nevertheless, there may well be a slow-down in the conversion of electric power stations from coal burning to oil burning and other moves may be made towards softening some of the blow likely to fall on the coal industry. But there is little likelihood of that happening in the gas industry. Our future—immediate future at any rate—seems to be increasingly bound up with oil. But, of course, although our research is concentrated upon the hydrogenation of oil, this offers a promising approach to the hydrogenation of low-grade coal. For the present our problem is survival; and that can only be achieved by keeping the price of gas down. If the industry can hold its own for the next few years circumstances may well be more in our favour. For better or for worse, there are some big changes ahead.

Sludge Gas

A SOMEWHAT naïve article appeared in the popular Sunday Press recently, criticising the West Midlands Gas Board for not purchasing for resale to its gas consumers, the sludge gas produced at the Coventry Corporation sewage works. In fact the Board has always been most anxious to make full use of gas from any available source, as is shown by the large supplies of methane taken from collieries in North Staffordshire. From this source too, it is willing to supplement its gas supplies, though the amounts involved are minute, equal over 24 hours to the Board's production in 55 seconds.

This sludge gas, containing 69% of methane, needs to be treated before distribution and would have to be brought to the Foleshill gasworks at the opposite end of the city for this purpose. Since it would be necessary to spend about £50,000 on the laying of mains and the installation of other equipment, the Board calculates that the cost of treatment before distribution is approximately 5d. per therm. They are offering a maximum of 5d. a therm to the Corporation, bringing the total cost of the gas before distribution to about 10d. a therm. The Corporation have refused this offer but in a Parliamentary Bill promoted in 1949 sought powers to supply gas direct to consumers without the consent of any gas board, and powers to break open streets to lay gas mains. Naturally the Board contested this clause in Parliament and the matter was heard by a Select Committee of the House of Lords. During the hearing a letter was submitted by the Minister of Power pointing out that there were no special reasons for justifying the Corporation being given powers contrary to the Gas Act, 1948.

After a full hearing, the clause was deleted. In spite of this incident, the Board is willing to buy the sludge gas at a reasonable price and renewed its offer as recently as January 29.

Translators Beware!

THE translation of technical papers from a foreign language into English almost always involves converting the other country's system of measurement to our own familiar British system. It is only for papers on subjects of pure science that this is unnecessary since scientists are perfectly familiar with the international system of measurement, the metric system. Among gas technologists and engineers who are accustomed to reading translated abstracts from papers or articles from the Continental gas Press in the 'GAS JOURNAL,' many will be familiar with the cubic metre and will be able to convert it instantaneously into 35.3 cu. ft.; but other measurements occurring on Continental drawings and diagrams, given in mm. are rather more difficult to envisage without a considerable mental effort. It is our practice, then, to convert in every possible case all c.g.s. (metric) units to f.p.s. (British) measurements. But such conversions must be made into units familiar to those who will be reading them. To convert 1 cu. m. to 1.038 cu. yards, as we noticed in a daily paper recently, is far more confusing for gas engineers than if it had been left unchanged.

Unfortunately this procedure must also be applied when 'translating' from the American. This is made necessary, not only by a difference in magnitude of what seems to the English reader a familiar measurement, such as gallons, billions or trillions, but also by some very confusing abbreviations. What British gas engineer, who was unfamiliar with American technological literature would guess the meaning of MCF at the first glance? Would he not read it as millions of cubic feet? He would be wrong. It denotes thousands of cubic feet. To indicate a million, the American would write MM, as in MMBtu. This in turn might often be 'translated' more conveniently into English as 'tens of therms,' rather than millions of B.t.u. These are some of the many pitfalls into which the unsuspecting translator may easily fall; there are many more.

Personal notes

MR. P. D. M. AIRD has been appointed Chairman of Glover & Main Ltd. and the principal associated trading companies, Thomas Glover & Co., Ltd., R. & A. Main Ltd., and Main Water Heaters Ltd. This follows the recent retirement of COL. W. R. GLOVER, C.M.G., D.S.O. Mr. P. D. M. Aird joined R. & A. Main Ltd. as an apprentice at their Falkirk works in 1933. During the war, from which he was demobilised with the rank of Major in the 7th Armoured Division, he was mentioned in Dispatches and awarded the Croix de Guerre, the Order of Leopold, and the Territorial Decoration. After the war, Mr. Aird became assistant to Mr. James A. Maclay, then sales director of R. & A. Main Ltd., becoming sales director himself on the latter's death. In 1947 he was appointed managing director of Main Water Heaters Ltd., and in 1949 he became deputy chairman of Glover & Main Ltd. In 1950 he was also appointed joint managing director of R. & A. Main Ltd., with Mr. C. Marley and in 1956 became sole managing director, relinquishing his similar position with Main Water Heaters Ltd., in order to devote more of his time to this new appointment. Mr. Aird is also Chairman of Morley Products (Padiham) Ltd., which position he has occupied since the acquisition of the company by Glover & Main Ltd., in 1955. Colonel Glover, a prominent figure in the gas industry for almost 60 years, has been made Honorary President of Glover & Main Ltd., in recognition of his exceptional service to the company. It is hoped that in this capacity he will find it possible to visit the various works from time to time and keep in touch with the progress of the group. He is a grandson of Thomas Glover, founder of the Company. Following distinguished service in the 1914-1918 war, Col. Glover was appointed managing director of Thomas Glover & Co., Ltd., in 1919, which appointment he held until 1953. He was appointed Chairman of Glover & Main Ltd., and associated trading companies in 1949. Col. Glover joined the Institution of Gas Engineers in 1931 and was elected an Honorary Member in 1955. He is a past-chairman of the Society of British Gas Industries, and a past-master of the Haberdashers Company. Initiated into Murdoch Lodge in 1911, he is a past-master of that lodge and of lodge No. 26, of which he is also past-grand steward.

MR. J. CASTLE, General Manager of the North Western Gas Board's Wirral Group, has been appointed General Manager of the Liverpool Group of undertakings in succession to the late MR. J. G. O. DRAKE. For the time being Mr. Castle will continue to be the General Manager of the Wirral Group, and MR. C. W. SMETTEM will act as Assistant General Manager of that Group, in which he will exercise control under Mr. Castle's direction.

MR. C. H. CHAPLAIN, manager of the Publicity department of The British Thomson-Houston Co., Ltd., has retired after 47 years' service with the company. A native of Stafford, Mr. Chaplain went to Rugby in 1912 to join the staff of the B.T.H. Switchgear drawing office after a short spell with British Westinghouse (now Metropolitan-Vickers Electrical Co., Ltd.) at Trafford Park, Manchester. This followed an apprenticeship with Siemens Bros., Dynamo Works Ltd. (now English Electric). In 1913, Mr. Chaplain joined the then newly formed Publication (now Publicity) department, of which he became manager in 1948. MR. H. G. HARLOW, who succeeds Mr. Chaplain, received his early education in Bristol, subsequently graduating from Bristol University with a B.Sc. degree in electrical engineering. He joined B.T.H. in 1920, transferring to the company's London office in 1932, and was appointed manager, Leeds District, in 1948. In 1955 he became manager of the Newcastle District office.

Correspondence

Safer than electricity

DEAR SIR,

I wonder if many people in this industry have realised the advantage it can gain over the electrical industry by producing non-toxic gas. When that time arrives gas will be a far safer fuel to have in the house than electricity. It would be worth 1d. a therm in increased costs.

It has been suggested that gas receives a very poor press compared with its electrical counterpart, but this is hardly borne out by my book of cuttings taken from our local morning and evening papers over the past three and a half years. To date 'Shocking Events' contains 80 cuttings relating to different cases of accidental deaths, fires, power failures and suicides attributable to electricity.

The condition of wiring and electrical appliances in the older houses must be a headache to both the industry and the fire brigade officials. In this connection one of our Sunday papers gave a vital warning under the surprising heading 'You can't smell electricity,' and mentioned 579 deaths in 1956 due to 4,862 blazes.

Yours faithfully,
'F. H.'

York,
February 10, 1959.

Obituary

MR. GEORGE HARRISON, head of the Brickwork Drawing Office Department of Drakes, Ltd., died on February 9. He had completed 50 years service with Drakes, Ltd., and was due to retire at Easter this year. He was a director and assistant general manager of a subsidiary company of Drakes, Ltd., John Morton (Fireclay), Ltd., and was very well known to many people in the gas industry.

Diary of forthcoming events

February 21. — SCOTTISH WESTERN JUNIORS: Dumbarton. Conducted tour of gasworks; lunch at Dumbuck Hotel and a paper on 'Management and Plant,' by A. M. Jackson. 10.30 a.m.

February 24.—MIDLAND JUNIORS. 'The Commissioning Procedure at the Walsall New Works' by G. W. Harvey, Work's Superintendent of the Walsall New Works. 6.30 p.m.

February 24. — INSTITUTE OF FUEL, SCOTTISH SECTION: Royal College of Science and Technology, Glasgow. 'Present Trends in Research on Coking Properties of Coals,' by Helen McKellar. 7 p.m.

February 25. — INSTITUTE OF FUEL, LONDON SECTION: Institution of Civil Engineers, Great George Street, London, S.W.1. 'Investigations in Germany Concerning Atmospheric Pollution,' by Dr.-Ing. H. Lent. 5.30 p.m.

February 25. — WALES AND MON. JUNIORS, SOUTH WALES SECTION: Newport. Paper by Mr. H. Breeze, Pipe-line Construction Engineer, Wales Gas Board.

February 25. — WALES AND MON. JUNIORS, NORTH WALES SECTION: Connah's Quay. Paper on 'Space Heating.'

February 26.—INSTITUTE OF FUEL, East Midland Section: Nottingham. 'Recent Developments in the Heating of Domestic Premises,' by Dr. S. A. Burke. 6.15 p.m.

February 26.—NORTH THAMES G.C.C.: City Hall, Westminster. Council Meeting.

February 27 and 28.—LONDON AND SOUTHERN JUNIORS: Bradwell-on-Sea, Essex. Joint visit with Eastern Juniors to the new atomic power station.

February 27 and 28.—EASTERN JUNIORS: Bradwell-on-Sea, Essex. Joint visit with the London and Southern Juniors to the new atomic power station.

March 2.—INSTITUTE OF FUEL, NORTH EASTERN SECTION: King's College, Newcastle-on-Tyne. 'The Early History of Gas Emission,' by Dr. J. H. Jones. 6.30 p.m.

March 3.—LONDON AND COUNTIES COKE SALES CIRCLE: Connaught Rooms, Great Queen Street, Kingsway, London, W.C.2. One-day Coke Conference.

Institution of Gas Engineers

WORK STUDY SYMPOSIUM HELD BY MIDLAND SECTION AT BIRMINGHAM

A SYMPOSIUM on work study was featured at the spring meeting of the Midland Section of the Institution of Gas Engineers held in the Department of Chemical Engineering in the University of Birmingham.

It included papers by Mr. J. K. Mitchell, Work Study Officer, No. 2 Division, W.M.G.B., on 'Work Study in Practice,' Dr. N. A. Dudley, Head of the Production Engineering Department, University of Birmingham, on 'Operational Research and its Application to the Gas Industry,' and Mr. S. K. Hawthorn, Divisional Engineer, Birmingham Division, W.M.G.B., on 'Work Study Applied to Continuous Vertical Retort Operation.'

Operational research

As a prelude to the meeting, members were invited by Dr. Dudley to visit his department. Here post-graduate courses are run for graduates of mathematics, physics, mechanical engineering, etc., to gain knowledge in production engineering and to qualify for the degree of M.Sc. in operational research.

It undertakes investigations into industrial problems, such as the most economical design of workshops, the calculation of the best use of machine tools, transport, etc., and has investigated work study problems at the Dudley gasworks.

Later, a number of members, limited unfortunately to 15, accepted an invitation to take lunch in the University Refectory.

FILMS AND MODELS ON LOAN

A NUMBER of civil engineering contracting firms have films and models which are available for loan to schools and universities, educational authorities, clubs, societies, professional associations and others similarly interested in civil engineering projects at home and abroad.

Up-to-date

An up-to-date list of these films and models has just been prepared and copies may be obtained free of charge from the Federation of Civil Engineering Contractors, Romney House, Tufton Street, Westminster, S.W.1.

Parents see their sons at work

'THERE is a very big future in the gas industry. It is important that we keep pace on the gas fitting side of piping gas to customers' houses.' This was said by the Southern Gas Board's Commercial Manager, Mr. W. H. Elkerton, at a parents evening, at the Board's Training and Education Department, Bourne Valley, Poole.

The evening was specially planned so that parents could see how the Board trained their sons to become gas fitters. Before visitors inspected the training shop to see apprentices at work, Mr. D. L. Hill, Training and Education Officer, explained details of the scheme whereby 213 apprentices based on Dorset and Bournemouth, Southampton, Portsmouth and Isle of Wight, Reading and Oxford, are being turned into first-class gas fitters.

Power-Gas add to employee amenities

THE Power-Gas Corporation, Ltd., of Stockton-on-Tees, recently opened a staff canteen which is one of the best of its type in Tees-side.

It has accommodation for more than 240 people and consists of a cafeteria capable of holding 160 people, a waitress service room where there is seating for 60, and a guest room for important visitors. The canteen was opened by the Mayor of Stockton, Alderman F. E. Wiseman.

It is the second amenity the company has opened for its employees within two weeks—the other was a new £20,000 pavilion on the firm's sports field.

Gasmen tour TV studios

More than 50 members of the Scottish Gas Board, Glasgow and Western Division, were conducted on a tour of the Theatre Royal H.Q. of Scottish Television, Ltd., by Mr. Alex. Buchanan, an STV sales executive.

The use of coal pipe-lines in America

SIR HAROLD HARTLEY, questioned whether Britain was making sufficient use of pipe-lines when he addressed the Pipe-line Industries Guild at Caxton Hall, Westminster, recently. In Ohio, he said, there had been in operation for nearly a year a scheme whereby coal, crushed and screened, was made into a slurry and pumped through a 10-in. pipeline for 110 miles.

The pipe-line was four to five ft. underground, and at the power station—the line runs from the Pittsburg Consolidation coal mine to the Cleveland Electric Power station—the slurry was dewatered and fed direct to the boilers. The saving, as against rail, was about 75 cents a ton.

Economy in Britain

The success of this method in Ohio suggested that there might be possibilities of economy in Britain, said Sir Harold Hartley. The main conditions were a steady flow of coal from an individual mine to a large consumer for a period of years.

Promising possibility

As the coal had to be powdered, the promising possibility seemed to be a steelworks where the coking coal could be cleaned during the process of dewatering.

The fact that the cost of coal transport to power stations was at present £18 mill. showed that there was something to cut. With the increasing size of the rationalised production units of the modern world, and the drive for economy, pipe-lines were certain of a great future.

Business machine firms combine

THE merger of The British Tabulating Machine Co., Ltd., and Powers-Samas Accounting Machines Ltd., which was announced recently, is an important event in British industry generally as well as in the field of business machinery in particular.

The combined company will be called International Computers and Tabulators Ltd. and will trade under this name. It is intended that the initials I.C.T. should be adopted for general use both in trading and financial connections. I.C.T. employs between 15,000 and 16,000 staff and its assets are valued at nearly £24 mill.

Remarkable business

Throughout the fifty years of its existence The British Tabulating Machine Company had built up a remarkable business of renting Hollerith electro-mechanical punched card equipment and electronic computer machines suitable for all types of large and medium-scale governmental, local authority and business undertakings. Its operations were conducted almost entirely within the United Kingdom and Commonwealth countries.

Powers-Samas, in its forty-three years of life, had correspondingly built up a highly successful business with similar institutions and organisations by both renting and selling mechanical and electronic punched card equipment suitable, not only for large and medium-scale undertakings, but also in the field of smaller businesses not covered by the Hollerith range. Powers-Samas operations overseas extended beyond the Commonwealth countries to the Continent and, on a small scale, to North America.

Works close down

Production of gas is to be ended at the Kirkintilloch and Kilsyth works at the end of February, when supplies will be available from other sources.

Smoke control quiz for local authorities

N.S.C.A. attacks Coal Board advertisements

A CIRCULAR has been sent by the Minister of Housing and Local Government, Mr. Henry Brooke, to local authorities in England and Wales, asking them to complete and return a questionnaire showing their phased plans for establishing smoke control areas year by year to 1963, stating the final objective, and the target year for the completed programme.

Novelty of powers

The Minister points out that 'about half the smoke in the atmosphere comes from domestic stoves and fireplaces burning coal. Most of it is discharged at low level.' The first response towards the creation of smoke control areas is said to be encouraging, taking into account the novelty of the powers and their purpose.

'But the Minister hopes that from now on it will be possible to make faster progress, especially in removing the smoke pall from the "black areas" where air pollution is worst. The task of bringing under smoke control the large number of premises involved is a considerable one, and in the Minister's view it needs to be systematically planned and executed by local authorities.

'Attention is drawn to the desirability of ensuring that new housing estates, whether built by the local authority or by private enterprise, should be smoke controlled from the outset.' The Minister 'has no wish to suggest that outside the black areas a systematic approach to more localised domestic smoke problems is not needed. But for the present he does not consider it necessary to ask Councils outside the black areas for similar information.'

Finally, 'the Minister further hopes that the small number of urban authorities in black areas who have not yet made a building bye-law for smokeless heating and cooking appliances in new buildings will now do so.'

Mr. P. D. Proctor, Permanent Secretary to the Ministry of Power, who was visiting Scotland recently, is seen here watching a meter being tested in the assembly shop of Thomas Glover & Co., Ltd., in Edinburgh. Right to left: Mr. J. L. Warrander, Senior Scottish Officer, Ministry of Power; Mr. Sydney Smith, Chairman of the Scottish Gas Board; Mr. S. Hall, Sales Director, Thomas Glover & Co., Ltd.; and Mr. P. D. Proctor.

The issue of the Government circular coincided with the passing of a resolution by the National Society for Clean Air, which has been submitted to the appropriate Ministries and to the clean air councils:

> That this meeting of the Executive Council of the N.S.C.A. notes with surprise and regret the appearance of advertisements on behalf of the domestic raw coal fire. This major cause of air pollution was condemned by the Government Committee on Air Pollution (the Beaver Committee, and the recommendations of which accepted by Parliament and embodied in the Clean Air Act. To encourage the coal fire cannot but render more difficult the transition to smokeless methods of domestic heating (including smokeless open fires) and the extension of smoke control areas, and is thus contrary to a policy decided by Parliament to be in the national interest.

For school heating

A conference of local authority representatives and industrialists has been called for March 11 in Glasgow by the Scottish Fuel Efficiency Committee and the National Society for Clean Air.

Sir Patrick Dollan, Chairman of the Scottish Fuel Efficiency Committee, said last week that all the education authorities in Scotland are to be approached with a request to introduce smokeless fuels for school heating. An approach was also being made by the Committee to the Government asking for the abolition of purchase tax on gas and electrical appliances for household use.

Halifax Health Committee has given preliminary approval to two further smokeless zones in Halifax in addition to the central area zone which has been confirmed and comes into operation on October 1.

The inaugural meeting of the recently-formed Clackmannan County branch of the Women's Gas Federation, held in the gas showrooms at Alloa, was addressed by Mrs. G. Evershed, Chairman of the Federation.

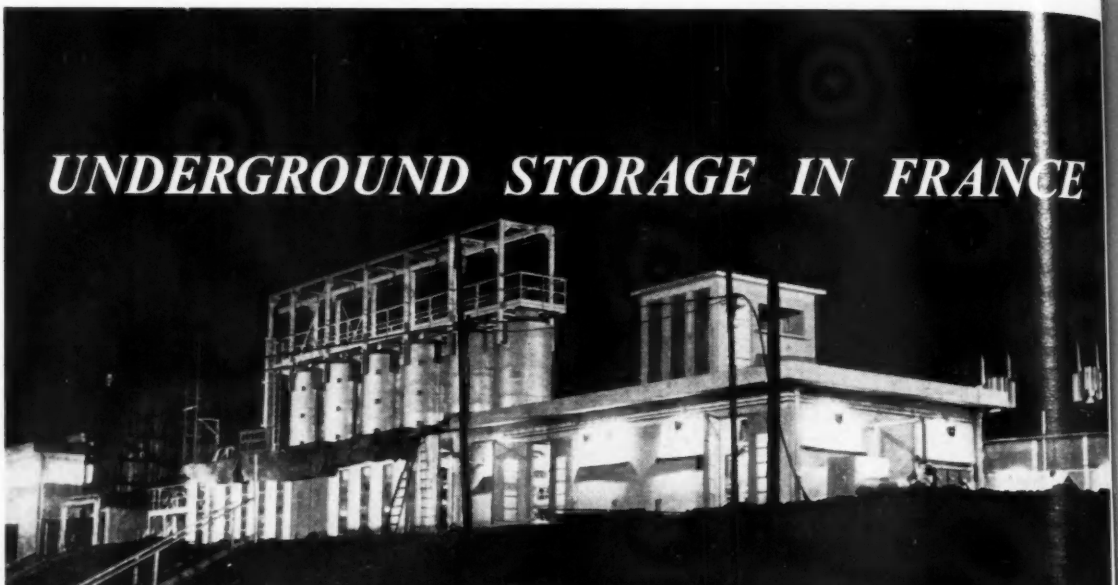
Juniors' Saturday events attract big 'gates'

YORKSHIRE JUNIOR GAS ASSOCIATION short paper day held at Wakefield on Saturday, February 14, had an attendance of over 70.

The President, Mr. R. E. White, was in the chair and the gathering was warmly welcomed by Mr. J. M. McCluskie, Group General Manager for Wakefield, who said he continued to be amazed at the number of members of the Association who were prepared to give up their Saturday afternoons to attend meetings.

The first paper 'Holder Anti-freeze with Water Circulating in Immersed Coils,' was given by J. M. Walker, Group Industrial Engineer, Bradford Group; the second, 'Some Experiences at a Large New Works,' by E. Haslam, Assistant Works Manager at the Tingley works of the Leeds Group, and the third 'Space Heating of a Church Hall,' by E. Ryan, outside sales representative with the York-Harrogate group of the N.E.G.B.

Sir Robert Nimmo, Chairman of the Scottish G.C.C., told South-West district committee members that the local gas showroom, since opening on Saturday afternoon in preference to Wednesday, the local half-holiday, had been returning the best results in the area.



UNDERGROUND STORAGE IN FRANCE

With Parisian demand forcing up production

unconventional methods were called for

By

MAURICE MOYAL

WHEN it comes to storing gas, American operators can generally rely on some depleted oil or gas reservoir. No special problems are posed. It is clear that the good reservoir rock which had prevented the escape of hydrocarbons to the surface for untold aeons will continue to hold the stored gas. Moreover, the reservoir pressure and production data logged during the life of the deposit will come in handy for calculating future reservoir performances. It is thus no wonder that 200 underground storage projects are currently in operation, under way or planned in the U.S.A.

Since France cannot use large depleted gas or oil fields, the local development of underground gas storage has had to blaze new trails. It has perforce to make do with aquifers, which have never before produced hydrocarbons.

Peak load

The story started in the early fifties, when rocketing demand for gas for heating houses in the populous Greater Paris area (it shoots up in winter to four times the summer consumption) compelled the local Gaz de France board to go an unconventional way. It was at that time imperative for the progressive public utility, which had begun to bring coke oven gas from the 200-mile afar Lorraine steelworks, to find big capacity storage in the vicinity of Paris, so as to stabilise the year-round load factor, and to meet the peak regional demand. The Greater Paris area will be using gas to the tune of well over 350 mill. cu.ft. daily by the 1961-62 winter, representing exactly a half of the country's total consumption.

Towards the end of 1953, Gaz de France settled on underground storage in some conveniently spotted local aquifer—despite the trouble that had already begun to beset America's Herscher Dome project, situated near Kankakee, Illinois. In April, 1953, Natural Gas Pipeline Company had started injecting natural gas into this huge aquifer to cater for the spiralling winter demand in the Chicago-North Illinois area.

After a lapse of four months, 33 water wells in the nearby village of Herscher began spewing gas totalling around 5.250 mill. cu.ft., out of an injected 200 mill. cu.ft. daily. The fluid, forced into a 1,750-ft. deep zone, had found its way into shallow holes, only about 100 ft. in depth. This has started a maddening five-year hue and cry, still under way, to pinpoint the leak points so as to cut them off. Meanwhile, to prevent a dangerous pressure build up, the company had to stop operation and to core into the shallow Gallena formation pressured with gas vent holes hard by each input well. This step eased up the leakage in the Herscher village, without stopping it altogether. It was subsequently checkmated by the provision of a special gathering and treating system.

After using all known leak detection tests, and devising several new tracer ones, the operator has narrowed down one major leak to the southern sector of the Herscher reservoir and one minor leak to its northern tip. But engineers are still in the dark about what causes them and how to seal them off.

Cover rock

This case in point illustrates the tough problems which storage in aquifers brings to the reservoir engineer. A necessity is good cover rock, unaffected by fault or fracturing, which provide an outlet for the injected gas to escape to the surface alone. The base must be closed by water, for, as the gas is injected into the formation, the liquid is progres-

sively forced away from the input wells to the outer edges; so a leak would occur if the water-line fell below a certain level.

Conditions of near-equilibrium practically exist between water and gas at any location in the reservoir when immobile. This balance is maintained during gas storage operation when the liquid travels freely in the reservoir. Thus, storage in aquifers is characterised by a roughly constant pressure and a variable volume, whereas it works out the other way round in depleted oil or gas structures, containing no water.

Ease of flow

In the former case, the storage capacity of the chosen reservoir depends on pressure, the size of the structure and its porosity. Individual well capacity during operation is directly related to the ease of flow of the fluids through a porous material, the shape and dips of the formation, and to the intensity of the water-drive and coning.

When the reservoir rock is characterised by favourable porosity and permeability, and when the formation is large with a high degree of lateral continuity of permeability profiles, the liquid travels freely through the reservoir during withdrawal.

There is then an expansion and flow of the reservoir fluids towards the producing wells. This allows the pressure of gas to remain roughly in near equilibrium with hydrostatic pressure. Such an active water drive permits to recover most of the pressure forced during injection. Worthy of note is the fact that the contrast in the density of the injected gas and of the reservoir water acts to produce a low volumetric sweep efficiency.

When withdrawing at high rates, water-coning may occur. It results in the deformation of the water-line perpendicularly to the withdrawal wells, and in the displacement of gas, causing such to produce water. The matter is still complicated by the presence of a zone of gas-water emulsion between the gaseous and liquid phases, and by the existence, above the highest level of the water-line, of an intermediary area where capillary pressure maintains a liquid saturation that varies in accordance with the height of the reservoir.

Reservoir pressure

Capillary retentive forces restrict still further the fluid-flow capacity. Thus, the flowing water-gas ratio depends to a certain extent on the reservoir liquid saturation, which is directly related in turn to the reservoir pressure.

In actual operation, the above factors are translated into a 50% reduction in the usable storage capacity of aquifers. A huge bubble above the top of the water-line must form a large gas cushion, which goes to remove the gas-liquids interface sufficiently farther from the bottom of the producing wells. Another, although very much smaller, amount of gas gets dissolved in the water, or trapped in the pore space volume through capillary action.

Engineers kept all this in mind when looking for some suitable aquifer, in the vicinity of Gaz de France's high-pressure gas-system that girdles Paris. It proved a tough job; in this flat country deep-seated structures have no surface expression, the subsurface bearing little relation to the surface. With the help of the French Petroleum Institute, they finally hit on the Beynes structure, situated in the Versailles forest, 25 miles west of the country's capital.

In 1954, the gas board drilled here a stratigraphic test 1,529 ft. into the jurassic, which revealed the existence of two superimposed layers. Lying at about 900 ft., the shallower green sands of the Albo-Aptian age were tapped by some local water wells. It was thus decided to explore the feasibility of storing gas in the deeper infra-cretaceous-Wealdian formation, topped at 1,312 ft.

Ten shallow core drills were sunk to the tertiary-cretaceous interface to check on the adequacy of the cover rock overlying the structure. It was ascertained that the regional cap rock is made of 23 to 30 ft. thick plastic marls. The top of the Albo-Aptian was mapped and the structure plotted. Another series of 12 slim holes were taken through the Wealdian into the top of the underlying jurassic. It was found that the intended storage formation is made up of fine-grained sands, interfingered with thin marl beds. It has a 30-35% porosity—cut down to an effective 21-25% by the presence of interstitial water—while permeability works out at an exceptional 4-8 darcys. A first test revealed that the fluids flow easily in the formation and that its water-drive is active.

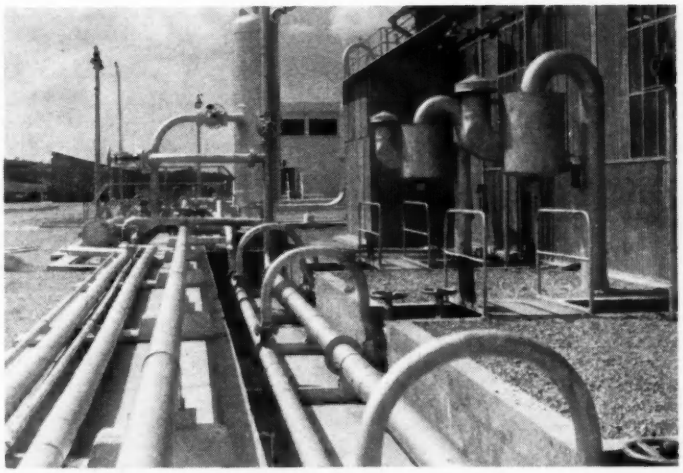
Pressure-tests were conducted to establish whether the marl cover rock was not more porous in certain streaks and whether unwarping of the formations that make up the structure has not caused undetected fault or fracturing. These tests indicated that favourable results could be expected.

Drilling went to show that the Beynes closed and very elongated dome is about 2 miles long, 1.5 miles wide and covers slightly less than 2.5 sq. miles in area, with a 102 ft. closure. Reservoir pressure ranges from 415 p.s.i. absolute in the crest to about 622 p.s.i. absolute in the flanks. Pilot tests showed that the Wealdian sand could hold from 11.2 to 12,000 mill. cu.ft. of coke oven gas, about half of which is usable, against Herscher Dome's 101,000 mill. cu.ft. ultimate storage capacity.

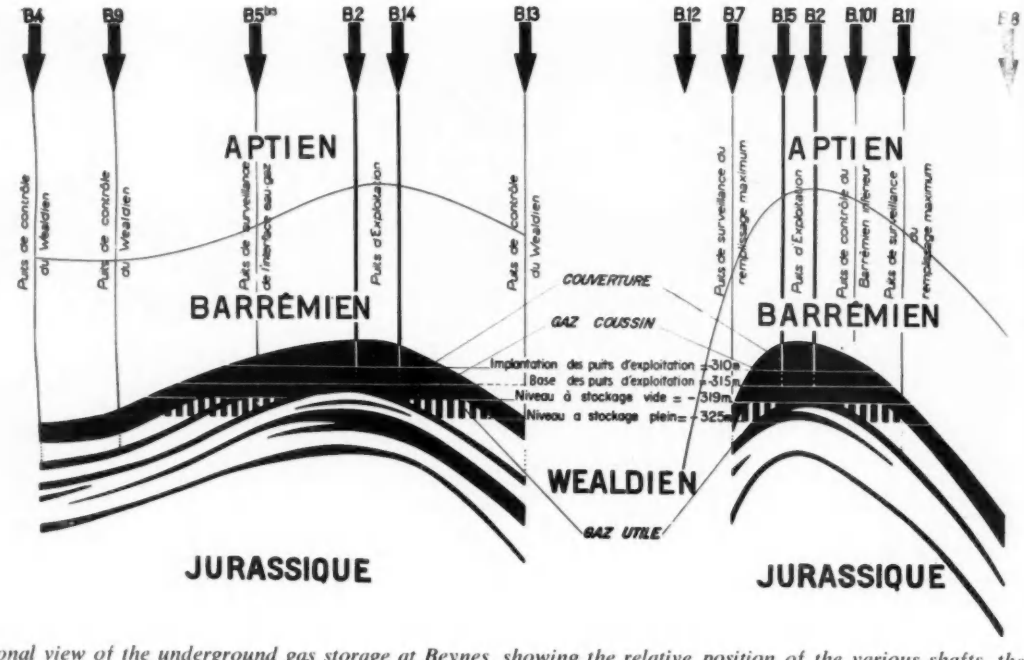
Relatively important

Although relatively small, the Beynes storage capacity was deemed sufficient to cater for the rising Paris demand for the oncoming years. But as it turned out, the height of the water-gas emulsion zone is relatively important in relation to the total extent of the vertical displacement of the water-gas interface.

As findings were more or less



The picture at the top of the opposite page is a night view of the installation at Beynes depicted above from another angle.



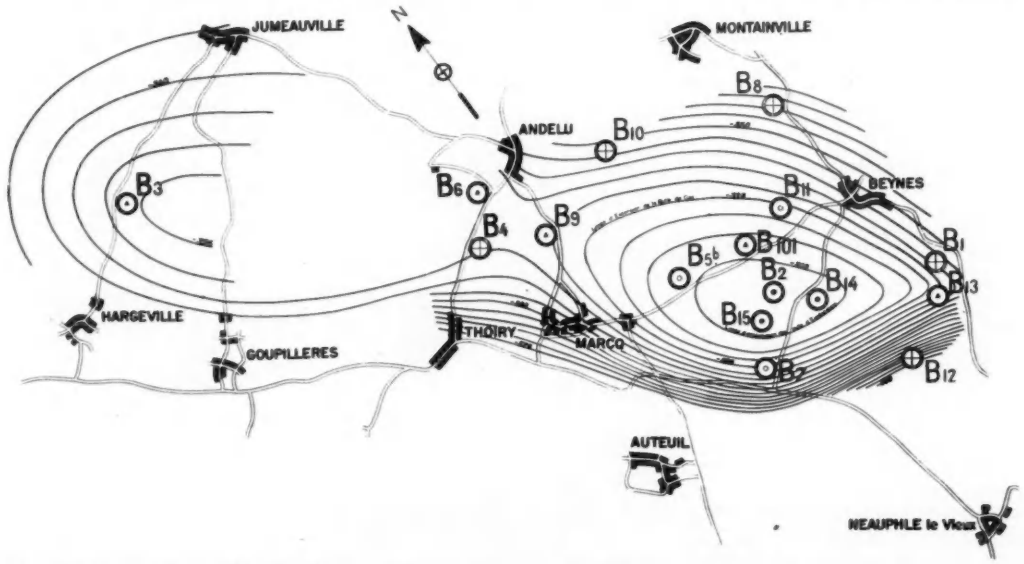
Sectional view of the underground gas storage at Beynes, showing the relative position of the various shafts, the actual area of gas storage, and the levels of the production wells.

Puits de contrôle du Wealdien—Control shafts into the Wealdian strata; *puits de surveillance de l'interface eau-gaz*—water-gas interface inspection shafts; *puits d'exploitation*—production wells; *puits de surveillance du remplissage maximum*—maximum refilling inspection shafts; *puits de contrôle du Barrêmien inférior*—control shafts into the lower Barremian strata; *couverture*, covering; *gaz coussin*—gas cushion; *gaz utile*—usuable gas; *implantation des puits d'exploitation*, position of production wells; *base des puits d'exploitation*, bottom of production well; *niveau à stockage vide*—water level, storage empty; *niveau à stockage plein*, water level, storage full.

favourable, the gas board followed up by completing six input-withdrawal wells in the Wealdian on the crest of the producing zone—another four drilled on the top of the dome for checking purposes proved useful in gas storage operation. The number of producing wells was subsequently doubled.

Gas bubble

Another group of six tests were brought in at downdip locations on the flanks of the structure to observe the water-level in the Wealdian, while the overlying Aptian and the underlying Barremian formations each came in for one observation hole. Still another series of six tests were drilled to follow the movement and effect of the gas bubble to be created.



Plan view of the underground formation and the position of the various shafts and wells referred to in the legend.

Finally, two holes were sunk on the extreme eastern tip of the structure to tap water for the compressors and treating system.

Actual injection began in the winter of 1956 through the highest wells on the structure. Gas for injection came through an 18-mile, 16-in. steel line to connect with the Paris gas-system at Viroflay.

To obtain, after final treatment, a practically pure fluid, so as to insure trouble-free storage in the Beynes reservoir, it was decided to transport it under pressure. At high pressure, on withdrawal the carbonic gas contained in the coke oven gas acts in the presence of water as an acid. Moreover, no condensation must take place in the line during injection, to prevent both the formation of hydrate that would plug it and corrosive action. So as to ensure optimum separation conditions and a drier gas, wellhead separator and a dehydration system have been provided at Beynes. The stainless, seamless line has been internally coated with especially cold-treated epoxy resins to resist corrosion.

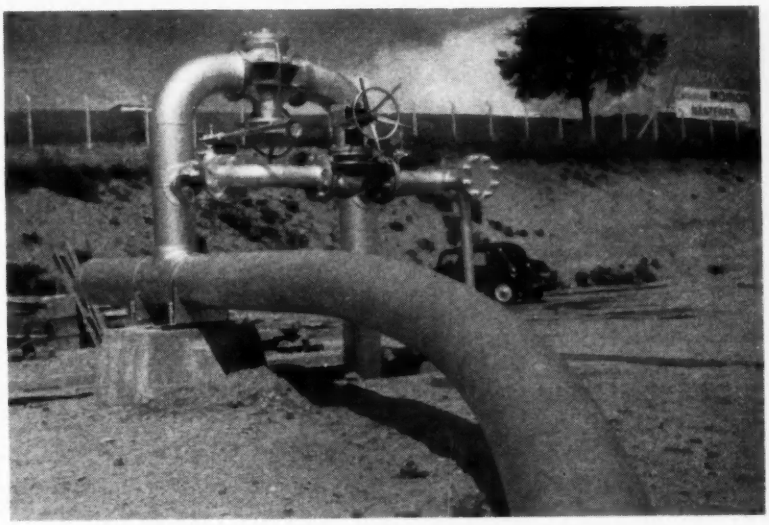
The gas is delivered by the line at a pressure of 250 p.s.i. absolute into the Beynes plant. It is first passed through a Blaw-Knox oil-filter. Three 400-h.p. compressors with a rated capacity of 17.5 mill. cu.ft. daily are used to give a maximum 622 p.s.i. absolute, for the gas must be forced into a reservoir at a pressure in excess of hydrostatic pressure, working out itself at 570 p.s.i. absolute. Cooling in a Fin-Fan column considerably reduces the heat generated in the gas by compression.

Activated charcoal

The stream is then passed on to the purifying system consisting of two pre-filters and four absorbers arranged in tandem for alternate operation. The medium used is activated charcoal, especially treated so as not to crumble at the high pressure and temperature to which it is subjected. The total charge of charcoal adds up to 300 metric tons.

One section is used for partially stripping out heavy benzole fractions, traces of ammonia, and sulphurous and cyanic components, while the other is being regenerated. In turn, this section will remove the remaining amounts of benzole and 'resinifiable' hydrocarbons.

It is imperative to get rid of unstable C_4 and C_5 because they tend to form solid components through polymerisation at the contact of the small amounts of nitrogen oxides, also carried by the coke oven gas. The high pressure and temperature the gas is subjected to in the underground reservoir, the considerable water-gas interface area and the extremely fine and porous sand particles all combine to favour such 'resinification' reactions, which would result in plugging the pore space volume in the vicinity of the producing wells.



The input piping while under construction.

This treatment goes also to remove those components that might, even in insignificant amounts, give water an obnoxious smell, were the stored gas to escape into some exploited aquifer. Noteworthy is the fact that, after withdrawal from the underground reservoir, the purified gas is given at the Viroflay plant an addition of benzole and gets eventually re-humidified, apparently to promote better utilisation on existing appliances.

Withdrawal trial runs were conducted in February and March. During a first five-day lapse, gas was withdrawn through five producing wells to the extent of 437,000 cu.ft. daily for a total of nearly 2.3 mill. cu.ft. No water-entrainment was noted, but the fluid produced was characterised by a relatively high degree of moisture. During a severe cold spell, the daily rate of withdrawal was subsequently pushed up to 28 mill., then 34 mill. cu.ft. through eight wells, without causing either water or sand-entrainment.

Current capacity

Thus, gas-storage performance has been so far excellent and closely parallels the gas board's initial expectations. The Beynes reservoir currently stores nearly 6,000 mill. cu.ft. of injected gas. The development programme has steadily raised production capacity to a current 42 mill. cu.ft. daily, and will be boosted to 105 mill. daily by the 1959-60 winter.

Gasworks profit 'ridiculous'

A NET profit of £688 made by Lurgan gasworks, Northern Ireland, in the year ended March, 1958, was criticised by several members of the local Borough Council at a meeting.

Councillor A. Houston said that on a turnover of £92,000 such a profit was ridiculous, and no businessman would tolerate it.

Mr. W. G. Best, Town Clerk, pointed out that there had been an overall profit of £2,688, of which £1,500 had been set aside for repairs to retorts, and £500 in reserve for income tax.

Asked by Councillor J. A. McCormick if the gasworks was being run for profit or to provide a service for the ratepayers, the Mayor, Councillor R. J. Brown, said its main function was to provide a service to the community.

Councillor W. J. Gordon said that at present consumers were being 'fleeced.' They might put a shilling in the meter in the morning and be lucky if they could get their breakfast out of it.

The Council decided that after members had studied the auditor's report there should be a special meeting at which the gasworks manager and auditor would be present.

Net profit of the British Vacuum Cleaner & Engineering Co., Ltd. Group, for the year ended September 30, 1958, was £127,672. A dividend of 7½% is recommended to ordinary shareholders.

INTRODUCING THREE

New Season's Cookers

★ **Radiation's New World Seventy Seven**

★ **Flavel's three-burner Courier**

★ **And the New World Seventy Two**

ANOTHER STEP FORWARD IN DESIGN

RADIATION have taken another step forward in gas cooker design in their New World Seventy Seven. This cooker brings the features of a luxury range within the reach of the housewife with a small kitchen, including a large eye-level grill, a self-heated warmer, four Radoflex boiling burners with automatic ignition, a capacious oven with drop door and removable top lining, a storage drawer and a four-hour timer.

The construction of the cooker is based on the grey vitreous enamelled front frame. The bottom angle-iron chassis members are fixed to this frame and these serve as legs for the cooker, and also provide the runners for the storage drawer. There is a short, sheet metal plinth panel fixed to each of the angle sections. The oven assembly, which consists of vitreous enamelled pressed steel sides, bottom, top and back screwed and cemented together, is also screwed and cemented to the front frame.

The oven, which is large enough to cook a 9 in. cake, four 2 lb. loaves of bread or a 22 lb. turkey, has a removable top lining and the well-known easy-clean sides. The oven burner and burner box are also removable. The oven is controlled by a combined Regulo and oven tap and it has a liquid type detector which is fitted above the top lining. The lagging consists of glass fibre blankets covered by aluminium foil, a combination having low heat capacity and high insulating quality.

The usual oven furniture is provided, comprising two oven grid shelves, meat tin and cake tray.

The drop door consists of two pressed sheets fixed together. Effective sealing is obtained by the deep re-entrant section of the inner door panel and spring steel bedding strips fixed between the oven shell and the front frame. The hinge and springing system is such that a check is provided before the fully closed position to prevent slamming.

At the top of the front frame the pressed metal hotplate side panels are fixed and these form the hotplate well. Both the bottom chassis members and the hotplate side panels are fixed to a pressed metal outside back at the rear.

The hotplate burners are of the latest Radoflex pattern with detachable caps and rings. They, in combination with the safety taps which must be pushed in before being turned on, allow a smooth, gradual turn-down of the flames from full-on to a mere glimmer for simmering. At the front there is a large burner and a smaller one with a similar arrangement at the back to allow a choice in each case according to the size of pan. The burner bodies are situated in the hotplate well; they fit on the injectors at the front and are held in position by clips at the back. Each hotplate burner is provided with automatic ignition which is supplied by a permanently burning pilot and an individual lighting jet for each burner. The pilot is controlled by a tap which is situated between the two front burners under a chromium plated cover.

The hotplate top is deep pressed to hold spillage and encloses the burner bodies and ignition system. The removable burner caps and skirted rings are situated above. The twin pan supports, which are grey vitreous enamel cast-iron, are identical and interchangeable.

Self-heated warmer

There is a large warmer with drop door which is supported above the hotplate by angle iron members fastened to the back of the cooker, the intervening space being covered by a pressed steel backplate incorporating the oven flue outlet. The warmer, which will hold the plates and dishes for a meal for six people, is heated by its own multi-flame jet with spreader.

Two grids are provided, one of which has legs and can be removed for use as a cooling tray for cakes or stored at the top of the warmer to give additional headroom.

There is a large eye-level grill above the warmer, the top of which is used to support the grill pan complete with brander-type grill pan grid. It will hold eight lamb chops or three slices of bread from a 2 lb. loaf for toasting.

To the left of the eye-level grill is a four-hour cooking timer, while on the right-hand side are the taps controlling the grill and warmer. The space below the oven is used for a storage drawer which, when the oven is in use, provides a measure of warming for plates and dishes.

The Seventy Seven is available in cream or white Radiation stain-resisting enamel. A gas taper with matching handle and a 150 D.A. governor are fitted as standard.

The dimensions of the cooker are:

Overall.—Height, 60¼ in.; width, 25¼ in.; depth, 22½ in.

Heights.—To hotplate top (over pan supports), 31¼ in.; to bottom of warmer from hotplate (back) 11¼ in., (front) 13¼ in.; to top of warmer from hotplate, 20⅜ in.; to centre of gas connection, 28 in.

Warmer.—Height, 5½ in.; width, 21⅛ in. (bottom grid), 22 in. (top grid); depth, 12 in.

Hotplate. — Width, 22 in.; depth, 17½ in.

Oven.—Height, 16 in.; width, 18 in.; depth, 14 in.

Drawer.—Height, 5 in.; width, 16¼ in.; depth, 15½ in.

Meat Tin (Internal).—Height, 2 in.; width, 13½ in.; depth, 9¾ in.

Cake Tray (Internal).—Height, $\frac{3}{16}$ in.; width, 14½ in.; depth, 10 in.

Grill Pan (Internal).—Height (to ledge), 1¼ in.; width, 14⅜ in.; depth, 7½ in.

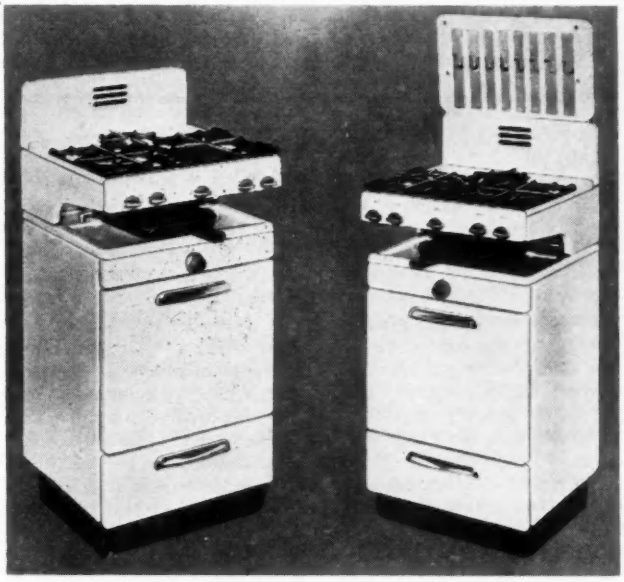
Grill Grid.—Width, 14¼ in.; depth, 6½ in.

The nominal burner ratings are:—

	B.t.u. per hour
Small Radoflex—l.h. back and r.h. front	7,500
Large Radoflex—l.h. front and r.h. back	12,500
Grill	14,500
Warmer	1,800
Oven	12,000
By-pass	1,300

—Radiation Group Sales Ltd., 7, Stratford Place, London, W.1.

EXTRA FEATURES MEAN PLENTY OF SELLING POINTS



THE Courier, an attractive three-burner small space cooker, has been introduced by Sidney Flavel & Co., Ltd. It conforms to the general dimensions of the Flavel Imp two-burner model, while incorporating extra features.

The platerack is an optional extra and is fitted in a jiffy by pressing the two rods into their sockets and fitting the platerack on to the brackets at the top. When not in use, the platerack can be dropped down to the wall surface.

The Courier retails at £25 15s. 0d. and the platerack assembly £1 15s. extra.

Specification

Hotplate. — Cantilever construction with glide-over one-piece vitreous enamelled top bar, with spill tray underneath. Three boiling burners and grill are positioned symmetrically in the hotplate.

Grill.—Located centrally in hotplate, and grill pan positioned by recess in fixed crown.

Oven.—Drop door; back burner; hinged roof for easy cleaning; vented through short splashplate.

Storage compartment.—Below oven, accessible by removing plinth front.

Fitting.—Flush to wall.

Colours.—White or cream vitreous enamel, and choice of six colours for plastic taps.

Dimensions.	*Height (in.)*	*Width (in.)*	*Depth (in.)*
Overall	41⅜	19¼	18⅜
Oven door opening	11¼	15⅝	
Oven inside ...	12	14 1/16	12⅞
Hotplate ...	35¾	18⅝	15¼

—Sidney Flavel & Co., Ltd., Eagle Foundry, Leamington Spa.

THIS TWO-UNIT MODEL CAN BE BUILT INTO THE KITCHEN

THE New World Seventy Two gas cooker has been designed as two separate units—the hotplate and the oven. These can be built into fitted furniture in the modern kitchen and located as to position and height in accordance with the wishes of the housewife.

The hotplate unit requires a recess of the following minimum dimensions: 8 1/16 in. high, 22 in. wide, 18 in. deep.

Easy movement

Most users will prefer this unit to be fitted with the boiler burner pan supports just clear of the adjacent working tops so that utensils can easily be moved onto and off the hotplate. The hotplate has four Radoflex boiling burners with detachable caps; two small ones at the back rated at 7,500 B.t.u. per hour and two large ones at the front rated at 12,500 B.t.u. per hour. The grill burner which is situated centrally beneath the hotplate top is rated at 13,500 B.t.u. per hour. These burners in combination with the safety taps—they must be pushed in before being turned on—allow a smooth, gradual turn-down of the flames from full-on to a mere glimmer for simmering. The signal stripes, horizontal in the off position, show by change of direction when a tap is on.

The twin grey vitreous enamelled pan supports which are of the open type, are identical and interchangeable and have been designed to provide a stable support for even the smallest pans.

The grill chamber is lined with vitreous enamelled panels and there is a removable pressed steel tray with embossings to guide the grill pan into its correct place. The central grill burner has a fret at either side and a cover fitted over the burner with an outlet slot discharging the products of combustion through a corresponding slot in the hotplate top. Full grilling heat is obtained very quickly after lighting and the grill is large enough to cook six lamb chops.

A built-in constant pressure gas governor is provided.

The oven unit can be fitted into a recess of the following minimum dimensions: 28¾ in. high, 22½ in. wide, 19 in. deep.

Working height above floor level can be chosen with full regard to convenience in operation and most users will probably prefer to have the oven at about chest height. This will give full view and access into the oven without stooping, and will allow best use to be made of the drop-down door as a temporary resting place for dishes at about waist height.

Latest Regulo

The oven incorporates the latest type Regulo control with adjustable knob, single back burner rated at 11,500 B.t.u. per hour, top flue outlet, easy clean side linings, bright chromium plated shelves and light vitreous enamelled finish. The door opens downwards and is controlled by a hidden spring mechanism which counterbalances the door when open and holds it firmly against the oven front when closed.

The Regulo control enables the user to repeat chosen cooking conditions exactly whenever desired. The oven is 16 in. high, 18 in. wide, and 14 in. deep and will accommodate a 22 lb. turkey.

To ignite the burner it is only necessary to put a light to the small hole in the bottom of the oven near the front and turn on the gas. Products of combustion are vented forward through a louvred outlet above the oven door.

Interior cleaning

The interior has rounded corners, wide shelf runners and a removable burner and burner box, all of which make for easy cleaning.

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COMBUSTION NOISE

From a paper to the Autumn Research Meeting of the Institution of Gas Engineers, November, 1958. A full report of the discussion follows the abstract.

By

J. K. KILHAM,
B.Sc., Ph.D., A.R.I.C.,

and

T. J. B. SMITH,
B.Sc.,

JOINT RESEARCH COMMITTEE OF THE GAS COUNCIL AND THE UNIVERSITY OF LEEDS.

THE problem of burner noise is important to the gas industry, since about 15% of the gas manufactured is used industrially in noisy equipment. This proportion is likely to rise in future with the more widespread use of high-velocity tunnel burners for local-heating operations.

In general, combustion noise may be divided into two types:—

1. Aerodynamic noise, which is emitted whenever a stream of high-velocity gases is discharged into the surrounding atmosphere. The noise possesses a broad frequency spectrum and has been shown to be caused by shearing forces at the jet boundaries. Highly turbulent flames also produce noise of this type.

2. Thermo-acoustic noise, which contains discreet frequency components and is most pronounced when a flame is enclosed in any type of combustion chamber. The flame acts as an energy source to drive standing waves at the natural frequency of vibration of the enclosure. Vortex shedding may also give rise to a similar type of noise.

Future research

In this paper, a selection of the relevant literature on aerodynamic noise and thermo-acoustic phenomena is presented. In addition, attention is drawn to the inadequacy of previous work on noise suppression as it affects the gas industry, and suggestions are made for future lines of research.

In order to keep in step with the demand for increased productivity in industry, considerably higher heating rates have become necessary during the last few years. The gas industry is meeting this demand to some extent by the development of high-velocity tunnel burners.

A grave disadvantage of tunnel burners is that they frequently give rise to a highly unpleasant noise, which can make working conditions practically intolerable, and, in the worst conditions, actually cause physical pain. In order to compete with electrical induction heating, which is silent, steps will have to be taken to reduce considerably the noise emitted by these burners.

It must not be concluded from the above remarks that tunnel burners are the only offenders as far as noise is concerned. In general, all high capacity burners are, to some extent, noisy.

The term 'aerodynamic noise' covers all forms of sound generation by turbulence, such as jet noise, edge tones, etc. A considerable amount of research has been made into the problem of the suppression of noise made by jets, but very few data are as yet available on the noise generated by open turbulent flames.

A fundamental theory of aerodynamic noise has been developed by Lighthill who has shown that the total acoustic power output is roughly proportional to:—

$$\frac{\rho_0 U\ l^2}{a^2_0} \text{ or } P \text{ (decibels)} \propto 8 \log U,$$

where ρ_0 and a_0 are the density and speed of sound respectively in the external atmosphere, U is a typical velocity in the flow and l is the jet diameter. The analysis shows also that the maximum acoustic radiation will occur at an angle of 45° to the jet axis, but this angle will diminish as the mean velocity is increased to an appreciable Mach number.

The ratio of acoustic energy to jet kinetic energy, or acoustic efficiency, may be expressed as:—

$$\eta = \frac{K \rho_i M^5}{\rho_0}$$

where K is the acoustic power coefficient (usually of the order of 10^{-4}), M is the jet exit Mach number, and ρ_i, ρ_0 are the densities within and external to the jet.

Experimental tests on model air jets have been carried out in numerous laboratories, both in this country and the United States of America, with a view to better understanding of the parameters affecting jet noise and methods of its reduction applicable to full-scale jet engines. The majority of published results are in fairly good agreement with Lighthill's theory.

Investigations of the apparent position of the acoustic sources within the efflux from a 1-in. jet have shown that, for a given frequency, the source is displaced downstream as the velocity is increased, and that low-frequency sources appear further down the jet axis than high-frequency radiators. Studies of subsonic and supersonic jets indicate that the point of greatest pressure fluctuation is determined by jet velocity and radial distance, with a tendency to shift downstream as either parameter is increased.

Since at long distances the jet may be considered to be a point-source of sound that is directional with regard to frequencies and pressure magnitudes, the noise level will be proportional to the jet velocity raised to a constant power. As the point of measurement approaches the jet, since it can no longer be regarded as a point-source, the value of this exponent will diminish.

Proportional

Different experimenters have found that the noise level in the far-field region is proportional to the jet velocity raised to a power varying between extreme values of 4 and 9, but in the near field the exponent has been found to fall to a value of 2·0 or less. The noise level has also been shown to vary as the square of the jet diameter as predicted by Lighthill, and the most intense frequency component to vary inversely with jet diameter.

The effect of temperature on jet noise has been investigated, and it has been shown that high temperature jets radiate a larger proportion of the available mechanical energy in the form of acoustic energy.

Thermo-acoustic phenomena in-

clude singing flames, organ-pipe oscillations, vibrating flames and many other forms.

As a typical example, when a gas is forced through a duct, one or more of the natural modes of vibration of the duct are always excited to some degree. The presence of a flame in the duct offers a source of energy to drive or damp the standing waves and hence thermo-acoustic noise is generally characterised by a small number of discreet frequency components. In many cases these flame-driven oscillations cause little or no annoyance or may be necessary to the functioning of a particular burner system, as in the case of a pulse jet. However, under certain conditions, burner oscillations can become so violent that they are extremely objectionable from the physiological point of view, and may damage or destroy equipment, interfere with proper combustion, or seriously affect the performance of propulsive devices.

Difficulties

It is difficult, if not impossible, to design a combustion system in such a way that no oscillation can occur, some of the reasons being as follows:

(i) Oscillations can be caused by many different combinations of conditions.

(ii) The exact mechanisms of driving are not known for some of the types of oscillations that may occur.

(iii) Resolution of a combustion system into components to make it mathematically tractable is difficult.

(iv) In the mathematical analysis, the values of certain terms, such as damping, are neither known nor easily obtained. Hence, at the present time, the usual practice is to eliminate oscillations by trial-and-error methods in order to obtain a quiet burner.

The most common form of combustion oscillations that has been observed is the organ-pipe type, in which the wavelength of the oscillation is related to the long dimension of the combustion chamber.

Higgins seems[1] to have made the first recorded observation of an organ-pipe-type oscillation caused by combustion, when he enclosed a hydrogen diffusion flame in a large tube open at both ends. For certain positions of the flame in the tube, and for certain lengths of the fuel supply line, audible oscillations occurred.

Other investigators have subsequently postulated an explanation of these oscillations and have devined a criterion whereby the periodic addition of heat drives a standing wave.

A hypothetical criterion advanced by Lord Rayleigh has proved satisfactory in practice, with the possible exception of cases involving large average velocities and large rates of heat release. In general, the criterion is that the point of heat addition must be other than a pressure node in the standing wave, and that heat added to the gas must have an oscillatory component, such that more heat is added during the high-pressure half of the vibration cycle than the low in order for spontaneous oscillations to be generated. In other words, the periodic component of the rate of heat addition must be in phase with the oscillating component of pressure.

Experiments have revealed close connection between spontaneous excitation of organ-pipe oscillations and flame front instability characterised by cellular structure. It has been suggested that, as a consequence of acceleration instability, the oscillation of the gas column alternatingly distorts and flattens the flame front, thus creating the observed vibration-induced cellular structure. These distortions in flame area cause in turn periodic changes of flame surface area and, therefore, of burning rate.

The heat addition can either drive, or damp, an oscillation.

Waves pass through the flame front with their velocity amplitude unaltered. When the net velocity causes a change in flame area, waves are propagated simultaneously into the hot and cold gases. When these flame-generating waves are phased with the existing components of the standing waves, they drive the standing wave; when opposed, they damp it.

Howland and Simmonds[2, 3] have investigated the noise produced by combustion inside refractory tubes. They noted that, below some critical length, the frequency increases with decreasing tube length, but that above this critical length the frequency is constant. By stroboscopic examination of the emergent flame, they showed that the oscillations arose as a result of successive explosions. When the combustion pulsation frequency coincides with the natural organ-pipe frequency of the combustion chamber, the oscillation reaches a high amplitude. This illustrates an instance in which the oscillations are not of the organ-pipe type, but will be reinforced by organ-pipe oscillations when the frequencies closely correspond.

In 1932, the American Gas Association embarked on a comprehensive programme to find the effect of different variables on the noise emitted by industrial gas burners. The work may be summarised as an attempt to reduce noise generation by providing good mixing of air and gas, and then eliminating turbulence and eddying from the mixture stream to the greatest possible extent. The amplifying and resonating effect of the burner tunnel was also studied. The American Gas Association project made no attempt to analyse the sound produced or to investigate the mechanism of its production.

Certain recommendations were, however, made, but these were based on practical experience in use, rather than on any guiding theoretical principles. It is evident that any future programme of research on combustion noise should not be conducted on an *ad hoc* basis, i.e., it is not sufficient to investigate the effect of varying parameters without some theoretical guiding principles. These principles may be derived, to some extent, from a study of previous fundamental work.

In the case of aerodynamic noise, the shearing forces at the jet boundaries must be reduced and it may be worth trying a modification of the methods at present used for silencing turbo-jet aeroplane engines.

The problem of thermo-acoustic noise is rather more difficult, and a consideration of the present theories shows that, in the case of tunnel burners, for instance, not enough attention is given to the portion that comes before the burner port (with the exception of turbulence elimination). The complete system, from the injector or proportioner to the tunnel mouth must be considered as a whole and the heat source (flame) must be sited in such a position that it damps and does not drive any standing waves.

Research on these lines is at present being conducted in the laboratories of the Joint Research Committee of The Gas Council and the University of Leeds.

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DISCUSSION

Mr. L. W. Andrew, Director, Watson House, said: I believe we all think now that one of our major projects is to do everything possible to capitalise the basic advantages of gas, and one of those is the high heat

release. Another major problem is to minimise the disadvantages: Two of the possible disadvantages are the need to flue, and potential noise. In reading through the paper I get the impression that the authors feel the problem of noise is capable of solution, even at the high rates of heat release which are needed in industry, which they speak about, and which undoubtedly we must have, and which I understand will get higher. Even at those they do suggest the high frequency oscillation of flames can be reduced, resonant amplification can be avoided by non-matching frequency of burner and furnace, and acoustical dampers can be used.

I would be glad to know if the authors would confirm my impression that relatively small changes in design of burner, design of tunnel, and location in a tube or furnace, can markedly affect noise. We are dealing with a delicate and unstable system, and it seems we have an opportunity to solve the problem and avoid excessive noise.

I agree, on the other hand, that we need very much more fundamental information more power to Dr. Kilham's elbow to produce this, to provide a basic solution and short circuit some of the rather tedious experimentation associated with *ad hoc* modifications, otherwise necessary on burner and design for a completely different purpose from that of reducing noise.

Marked improvements

At Watson House we tried out 12 burners, using the conventional type and also with modifications affecting type of tunnel, length of tunnel, tunnel diameter, angle of tunnel, port diameter and length of nozzle, and the improvements were, to our ears, marked. Our ears were somewhat indelicate; Dr. Kilham came along with proper scientific instruments and confirmed that the Watson House ear was not an unreasonable method of assessing noise. We came to the same conclusions.

Arising out of this purely practical work, a report has been prepared, with conclusions and recommendations, and has been submitted to the appliance manufacturers. I hope this will help in an interim solution while waiting for more conclusive results.

To turn to one or two specific points in the paper, I was most grateful for the section on terminology. One can talk loosely about phons; for example, a level of 60 phons corresponds to the noise level of normal conservation, whereas a mere 100 phons represents a pneumatic drill at 10 ft. These phons are a pretty big noise. It is also to be noted that phons give us a noise level in terms of equal loudness, and I would like clarification from the authors as to whether or not equal loudness means equal irritation at different frequencies, as presumably it is irritation we have to avoid.

What is noisy?

Also, have the authors' views on acceptable levels in phons and frequency for (a) industrial purposes at different background levels, and (b) domestic purposes, always very silent. We have, for example, a nice problem with the Society of British Gas Industries at the moment, who say the cooker burner must be quiet. They come to us and say 'What is noisy?' We say we know they are a little suspicious of our opinion on what is noisy. I believe here the authors can help us. They must know, otherwise they would not have dared to stand on a public platform and say 15% of industrial burners are noisy. Might I ask them, how noisy?

It is not merely a question of industrial gas, as at a different level of noise the competitive position for normal domestic use may be affected. For example, looking ahead, there is an increasing use of fans for the removal of products of combustion, forced draught heat exchangers may be a development of the future, and from time to time the most interesting claims are put forward for the advantages of submerged combustion or even pulsating combustion.

Mr. L. T. Minchin, Consultant: I am sure a great deal of gas consumption has been lost through noise, not only in industrial applications, but in commercial and domestic. I therefore hope very much, and I think Mr. Andrew does, that this work will not concentrate entirely on very loud noises, because in the commercial use of gas heating of buildings, etc., noise, even at 30 phons, can still be significant.

I hope Dr. Kilham and Mr. Smith will have second thoughts about the suggestion that the use of flat flame burners cuts out noise problems. Below that pressure at which it roars, it is noisy. I wonder whether that is due to the turbulence of the invisible shift of gas products which has not spread to the visible part of the flame.

There is a fresh problem of adjusting pressure on the burner to a relatively low figure which is awkward for the fitters and leads to inaccurate setting.

Another point which the authors ought to mention in their list of noises in the introduction is noises inside the brass work of the appliance. Again, they are small, but they are significant in domestic appliance design.

One comes back again to the question of flame noise, which is one of the most difficult. If there is an injector—and there still are injectors in some appliances—the flat flame has not taken over all appliances—you can to some extent smother that noise by surrounding it by absorbent material, but you cannot do that with the flame. We have to quieten the flame by some more basic alteration of design.

It is interesting that the turbulence of a flame is less than that in the unlit jet products. An ordinary small jet at 22 cu.ft. per hour will not go turbulent until .9, nine-tenths of an inch or 1 in. pressure, but the same unlit jet is quite turbulent at that pressure. Therefore the flame reduces turbulence, but we all know it increases noise. It must be that this has some relation to the earlier Gas Research Board work, to acount for the fact that this unlit jet becomes noisy when it is lighted.

Large flame

It would be interesting if the authors could try and produce a really quiet large flame. Can one make a large flame really quiet by straightening out the eddies and approach to the flame port and ensuring complete mixing? I think you probably can. It would be an interesting experiment to try, and from that, those of us who have to design appliances in which the burners are really quiet, not less noisy than a jet flame at close quarters, will have something to go on.

Mr. Trevor Ward, N.E.G.B.: It is with very great interest that we in the North-East region have read the paper by Dr. Kilham and Mr. Smith, and although the work now being carried out at Leeds University is not contained in this paper, it contains fundamentals obviously useful in that work.

Our interest in combustion noise stems from years ago. It was found that although work had been carried out in this country and in the U.S.A. on the design of small burners, the information was very meagre when designing large burners by scaling up the design of small burners, from which acoustic problems quickly emerge. The measure of sound can be realised when it is said that a 24-in. slot burner could be heard at a distance of half a mile.

This noise level in fact bears a direct relationship to the combustion intensity, and any effort by simple burner design modification to eliminate noise results in a reduction of combustion intensity performance. Our experi-

ence is that the maximum performance of resonant noise will result.

Dr. Kilham has made a clear distinction between a roar of the normal burner system and the shriek noise associated with tunnel burners, since it is clear they are both controlled by different parameters. The former would appear to be associated with the slow issue of inflammable mixtures present in the flame, and the latter would be associated with the complete opposite, that is, a very high rate of combustion.

There is no doubt that the use of a perforated back plate accentuates this phenomena, by vastly increasing the flame area, and only by using this method of admitting the air/gas mixture is it possible to achieve combustion of extremely high rates.

While it may be argued that such rates of combustion are infrequently obtained, and are not of immediate interest to the gas industry, many cases have arisen where it is necessary, particularly where we are competing with oxy-coal-gas for heating in installations requiring high product temperatures of 1,600-1,700°C. The losses involved in the combustion chambers can then form a large part of our heating potential.

Flame speed

Recent experience on the Continent has been gained on the use of methane in high velocity tunnel burners. Here it is found that resonant noise problems are virtually non-existent. It appears flame speed is of particular importance in burner design, and particular attention must be paid to encourage maximum flame area, to achieve high combustion rates. We should beware of information received from the United States where any adaptation of their burners to our gas may result in more noise trouble.

I saw some interesting high velocity burners in Holland, and was impressed by how much work they have done there. Although burners were small in size, applications of them were wider than ours in this country. They used them on commercial firing, pottery kilns, vitreous enamelling and the very large bar bending. In the first instance, one burner, in the pottery 50 burners, vitreous enamelling used 12, and bar bending 120 burners. It was significant they had one mixing device to control the whole banks of burners. The mixing device was arranged so that it was proportioned against any back pressure of the burner system, which enabled you to shut off banks of burners and still maintain the proportions. Investigation into this type of mixing device would be of great advantage to the industry in this country.

Mr. D. C. Gunn, Deputy Director, Domestic and Engineering Laboratories, B.C.U.R.A.: I would just like to remind my old colleagues about a case in which this question of noise just wrote off something which was, in fact, a very brilliant design of gas fire appliance, namely, the Vesta boiler. That has long since departed from active marketing; there may be one or two still in existence, but I can well remember that in the early thirties a number of these boilers were installed throughout the country, and they all failed, through noise.

It is important that this question of noise be tackled scientifically and thoroughly, and someone might look at the Vesta boiler again and see what was wrong with it. One can learn a lot from looking into the past.

Mr. W. T. Hird, Distribution Engineer, Wales Gas Board: In America, in connection with their transmission of natural gas, they have for some time run into a major problem of noise at decompression stations. One notes their pressures are much higher than any we have previously used in the gas industry in this country, although we are beginning to go up.

Within the last few weeks we have run into a nice problem on decompression stations, at 50 lb. per sq. in.; we have run into this noise problem also.

I was delighted to see the basic approach which Dr. Kilham and Mr. Smith had made to this question of noise, because I feel sure that that investigation will, before very long, have to spread rather further than combustion noise, into decompression noise, which can become very serious.

Dr. J. K. Kilham (in reply to the discussion): Mr. Andrew raised a point about the effect of small burner design on combustion noise. This is true; combustion noise does depend to a great extent on burner velocity, the gas ratio to burner velocity. Design goes slowly; we are working on the Lennox, and you have to be well away from any resonant position. This gets very difficult when you have chain burning velocity.

Sensitive regions

There was a question about phons: As to which frequencies are more important from the physiological point of view. It has been found frequencies from 400-2,000 cycles per second are annoying; they get into the hearing curve and hearing is more sensitive in those regions. On the other hand, there is some evidence that very high frequencies may have an effect on the brain. That has not been proved yet.

Mr. Trevor Ward made a point about noise levels: It is rather a vexed question. There has been some work done on it, but the results so far have varied. The American Acoustic School are working on that point; I cannot give you any data at present.

As to what is noisy, so far as industrial burners are concerned: In my opinion, anything in the region of 90 phons is noisy. We preferably go down to the region of 80, and if possible, lower, for industrial use, and for the domestic user, much lower.

Mr. Minchin's remarks were mainly concerned with domestic appliances. The flat flame burners which are used in gas fires: I have not given this a great deal of thought, but I cannot at present see how we can reduce that noise. It is due to turbulence, which is necessary for aeration, and we have not dealt with it.

As to flame reducing turbulence, this does apply to a certain extent, and I think there is still scope for that previous theory that some noise is due to explosion of small poppets of gas especially with the highly turbulent flame with a lot of non-recurrence. In a flame retention burner, for instance, some of this noise can be reduced by a suitable device. Some of them are fairly crude, but that does lead to a small pocket of gas passing through.

Mr. Ward brought out the point of the use of methane in Holland and in the United States. As I said before, it is well known that there is trouble from gases containing hydrogen.

Mr. Gunn mentioned a boiler with which I am not familiar. It must have been before my time: I do not know the principles of the boiler at all. I should have thought this was a resonant noise in a boiler, and I should have thought there was some scope for a half-way tube on that to dull the resonant noise.

Mr. Hird mentioned decompression noise. In the immediate future we will not have the staff to deal with noises of that type; we have to concentrate on combustion noise in the first instance.

GAS CREMATORS FOR BELFAST

Work has begun on the building of Belfast's £100,000 crematorium at Roselawn cemetery—a project first mooted 25 years ago.

Mr. Reginald Wesley, Director of Parks and Cemeteries, has stated that it is expected to be ready for use by the end of next year.

The Corporation has already purchased two gas cremators for the building at a cost of almost £6,000. Provision has been made in the plans for another two cremators.

ODOUR AND ODORISATION OF GAS

By

K. A. DEADMAN,

B.Sc. Assoc.M.Inst.Gas E.,

and

J. A. PRIGG,

B.Sc., M.Inst.Gas E., A.R.C.S., D.I.C.

LONDON RESEARCH STATION,
THE GAS COUNCIL.

THE odour of conventional town gas to most people is familiar and characteristic, and is generally considered sufficient to give adequate warning of the leakage of unburnt gas. For many years, the law has required that gas should have an odour. At first, the requirement was that it should have the 'distinctive pungent smell of coal gas,' but this was amended in 1951 to read that gas should have 'a distinctive smell.'

Where the change from manufactured gas to relatively odourless natural gas has taken place, as in the United States of America and elsewhere, the addition of odorants has been considered necessary. The recent changes or proposed changes in gas manufacturing techniques, and the use of natural gas and mine gas in this country, have given rise to the possibility of the production of gases less odorous than conventional gases; to comply with the law, these will require the addition of a substance to give 'a distinctive smell.' The consideration of the level to which such gases should be odorised has necessitated a study of the existing odour level of town gas and its possible variations. The present investigation was, therefore, initiated to assess the factors affecting the odour of conventional town gas, and to examine various materials as possible odorants for gases not having sufficient odour of their own.

Comparative levels

A preliminary to such an investigation was the need for a method of assessing the comparative odour levels of different gases.

In this connection it was considered that the most convenient and reliable means for making the assessment was the use of an odorimeter in which the gas or vapour is diluted with an air stream, and the mixture inhaled from a suitable nose-piece or funnel. This apparatus used in the tests is described, and includes a series of calibrated capillaries to measure the gas rate and an orifice flow gauge to measure the air rate. Observers are asked to describe their sensations when a definite concentration of material is produced. Of all the sensations of smell, the most easily defined is that of the threshold, i.e., the minimum stimulus at which any sensation at all is produced. Other sensations, such as a weak smell or strong smell, can be described only loosely. Because of ease of assessment, the threshold concentration is generally taken as a measure of the relative intensity of the odour of a material; for example, if substance 'A' has a concentration at the threshold of one part in 10,000 (0.01%), while substance 'B' has a concentration at the threshold of one part in 20,000 (0.005%), then, in general, 'B' is a stronger-smelling material than 'A,' and the threshold concentrations can be taken as a measure of the relative odour strengths, although at higher concentrations the subjective response would not necessarily be in the same proportion.

The use of the threshold in this way has the disadvantage that the more strongly smelling substance is represented by the lower value. It is proposed to overcome this by taking the reciprocal of the threshold concentration and calling it the odorosity. The odorosity of a gas can then be defined as the volume to which unit volume of the gas must be diluted to obtain the threshold of smell. In the example above, the odorosity of substance 'A' would be 1×10^4 and that of 'B' 2×10^4. For liquids, the odorosity is more conveniently expressed as the volume in mill. cu.ft. to which 1 lb. of the vaporised material has to be diluted to reach the threshold. These methods of expressing the odour levels of gases and liquids respectively have been used throughout this paper.

All the major constituents of conventional fuel gases are virtually odourless, and the odour depends upon the presence of small amounts of substances with relatively high odour levels. These compounds can be divided into two main classes—unsaturated hydrocarbons and sulphur compounds.

Benzole removal

The odorosity of gases produced by the carbonisation of coal does not vary greatly according to the carbonising system, and is of the order of $1—2 \times 10^4$. Where benzole removal is practised, the odorosity may be reduced by 10-50 per cent. Table I gives measurements made on the odorosity of other types of fuel gas.

Although the odorosities of refinery gases are comparable with those of conventional town gas, it is conceivable that

TABLE I

Odorosities of Other Gases

Gas	Type of Odour	Odorosity		Number of Results
		Range	Mean	
1	2	3	4	5
Catalytic oil gas (Onia-Gegi)	Like high calorific value C.W.G.	$1{\cdot}1 \times 10^4$ to $2{\cdot}2 \times 10^4$	$1{\cdot}7 \times 10^4$	9
Peak load oil gas	Pungent, aldehydic	$9{\cdot}2 \times 10^4$ to $13{\cdot}9 \times 10^4$	$11{\cdot}8 \times 10^4$	3
High peak carburetted water gas (approx. 70% + 30% C.W.G.)	Like C.W.G., but with petrol note	$2{\cdot}4 \times 10^4$ to $3{\cdot}4 \times 10^4$	$2{\cdot}8 \times 10^4$	4
Horizontal coal + Tulley (400 B.t.u. per cu. ft.)	Coal gas	—	$0{\cdot}8 \times 10^4$	1
Refinery gas (1)	Mercaptan/kerosene	—	$2{\cdot}8 \times 10^4$	1
Refinery gas (2)	Petrol	$1{\cdot}4 \times 10^4$ to $3{\cdot}9 \times 10^4$	$2{\cdot}6 \times 10^4$	7
Reformed refinery gas (1)	Sweet, paraffinic	—	$0{\cdot}9 \times 10^4$	1
Reformed refinery gas (2)	Naphthalenic	$0{\cdot}1 \times 10^4$ to $0{\cdot}9 \times 10^4$	$0{\cdot}5 \times 10^4$	11
Enriched reformed gas (1)	As reformed refin. gas (1)	$1{\cdot}3 \times 10^4$ to $1{\cdot}7 \times 10^4$	$1{\cdot}5 \times 10^4$	2
Enriched reformed gas (2)	Petrol	$0{\cdot}3 \times 10^4$ to $2{\cdot}3 \times 10^4$	$1{\cdot}1 \times 10^4$	20
Butane (odorised)	Mercaptan	$1{\cdot}0 \times 10^4$ to $1{\cdot}2 \times 10^4$	$1{\cdot}1 \times 10^4$	4

NOTES: (1) The reformed and enriched reformed gases (1) and (2) were obtained from the corresponding refinery gases.
(2) Commercial butane is odorised with a mercaptan odorant.

relatively odourless refinery gases might be obtained.

In addition, natural gas and mine gas, being largely methane, are generally odourless, and reformed gases obtained from these will almost certainly have very little odour. Where these are used, therefore, odorisation will be necessary to increase the odour level to that of conventional town gas, and an examination of possible odorants has, therefore, been undertaken.

Properties

The following properties of an odorant are considered necessary:—

(i) It should be chemically stable; i.e., it should be capable of storage and not be affected by other constituents of the gas nor by contact with materials commonly used in gas distribution and utilisation.

(ii) It should be economical; i.e., it should not only be reasonably cheap, but also have a high odorosity.

(iii) It should be easy to add to the gas in the proportions required.

The odorants used in America and elsewhere for odorising natural gas fall broadly into three main chemical classes: (i) Aliphatic mercaptans, (ii) aliphatic sulphides, and (iii) cyclic sulphides (tetrahydrothiophen).

All three classes of compounds contain sulphur and will, therefore, contribute organic sulphur to the gas. In general, the effect is small, and with the dosages normally recommended, these types of odorant will contribute only about ¼ to ½ gr. of sulphur per 100 cu.ft. of gas.

Promising material

From preliminary field trials it was found that tetrahydrothiophen was the most promising material for use as an odorant for town gas in this country. Comparisons with established American practice using different odorants may be misleading if applied to conventional British town gas supplies, owing to differences in behaviour when used with natural gas. Thus, while mercaptans are perfectly satisfactory with the latter, they are lost in long stretches of main carrying coal gas, on account of their reactions with the coal gas constituents not present in natural gas. Tetrahydrothiophene is much more stable in this respect. It is produced in commercial quantities in this country of approximately 95% purity. Its chemical formula is

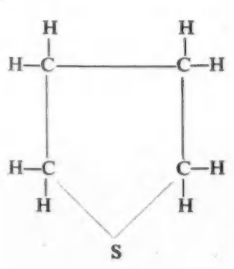

TABLE 2

Physical Properties of Tetrahydrothiophen

Density at 20°C (68°F)			0·9998 gm per ml
Normal boiling-point			121·45°C (282·6°F)
Freezing-point			−96·21°C (−141·2°F)
Flash-point			64°F

Vapour pressure (extrapolated)	°F	mm. Hg	°F	mm. Hg
	30	4·0	60	10·9
	40	5·6	70	15·9
	50	7·8	80	20·0
			90	27·0

The effect of adding an odorant to an odourless gas is, by definition, to increase the odorosity in proportion to the quantity of odorant added. When an odorant is added to a gas already possessing an odour, however, the effect is not so clear. The following are possible alternatives:—

(i) The odorosities are additive, the resultant odour being the sum of the constituents.

(ii) One odour merely modifies the other without producing an overall increase.

(iii) A synergistic effect is obtained, i.e., an increase in odorosity disproportionate to that of the constituents.

(iv) A masking effect is obtained where one odour tends to neutralise the other.

When a gas originally having an odour, but odorised with tetrahydrothiophene (T.H.T.) is mixed with conventional town gas of the same odorosity, the odorosity of the mixture will be less than that of either component. If results are plotted graphically, it will be seen that by adding T.H.T., very little increase in odorosity is apparent until the T.H.T. concentration approaches 1 lb. per million cu.ft.

Experiments were carried out on possibilities of reduction in odorisation by the passage of gas through soil. Tests were made to ascertain the relative odour absorption of conventional town gas and gas odorised with T.H.T. to the same odorosity.

Results

The gas was passed down a column of the soil of 3 cm. diameter at a rate of 0.5 cu.ft., per hour, and the odorosity of the outlet gas determined. The results obtained with moist and dry loam with town gas and nitrogen odorised with T.H.T. show that with moist soil there appears to be a greater initial rate of adsorption with odorised nitrogen, but the total adsorption is approximately the same for town gas and odorised gas. With dry soil, however, there is a marked difference between the adsorption of the odour of town gas and odorised gas. With town gas, the total adsorption is approximately twice that obtained with moist soil, while the adsorption with odorised gas is considerably more, about 100 cu.ft. of gas per lb. of soil being passed before the T.H.T. odour began to appear.

A relationship exists between the odorosity of town gas and complaints of consumers regarding leakage.

When the odorosity of distributed gas increases, there is a tendency for the complaints of leakage on the district to rise. These complaints are mostly confined to very small leaks and are usually associated with appliance taps, governor diaphragms and meter unions. Because of the smallness of the leaks, the question of safety is not involved, and at high odorosities the situation could arise that such leaks would be too small to locate and cure.

In considering odorisation, then, it is important to consider the opposing effects of under-odorisation with possibly reduced safety, and over-odorisation with a large increase in minor complaints.

It is difficult to make precise recommendations for the odorosity of town gas. It is suggested, however, that the odorosity should not be allowed to fall below 0.8×10^4. At the upper end, it will be seen that complaints of a minor nature rise rapidly above an odorosity of 3×10^4, and these values might be taken as reasonable limits.

DISCUSSION

Mr. G. E. Currier, O.B.E.: I fully agree with the authors that theirs is the best method for the assessment of odour strength.

The paper also shows that a considerable variation in odour level exists between districts using conventional plants and materials, although the minimum level seems reasonable at the moment.

In these days of grid systems and interlinkage it may well be that in the not too distant future all gas should be tested regularly to maintain the standards in a manner similar to those now made to enable our present statutory requirements to be met.

Gas produced at Tingley in the area of the North Eastern Gas Board from intermittent vertical chamber ovens has an odorosity of 1.9. Partial benzole stripping by atmospheric oil washing is in operation and the calorific value of the gas is 500 B.t.u. per cu.ft.

Field observations on artificially odorised gas distributed to a small self-contained district support the authors' findings that sufficient odorant must be added to overcome the natural odour of the gas before any appreciable increase is noticeable. In this case the gas distributed was a C.V.R./C.W.G. mixture of 500 B.t.u. per cu.ft. containing an average of 30% C.W.G. The base odour level of 2.0 was never sufficiently increased by the addition of 1 lb. T.H.T. per mill. cu.ft. to be noticeable. Nevertheless, reported complaints in the period April/

October, 1958, compared with those from an area supplied by similar gas without odorisation and related to the corresponding period of 1957 showed a substantial increase of complaints in the test area. This is somewhat baffling—can the authors help me?

Chief consideration in the paper is rightly given to the odorisation of gases of otherwise low odorosity. The accident level in areas where gas of normally high odorosity is distributed is also a matter of concern, and bearing in mind that the perception of odour reduces sharply in old people it could possibly be argued that odour levels generally should be increased, but more data is needed before this can be established. Dr. Sales in his paper to the International Gas Union suggested that all odour levels should be such that the presence of gas would be noticeable when the carbon monoxide concentration was 0.025%. This may have certain disadvantages, but a standard of safety might be attempted by variation of the odour level according to the carbon monoxide content.

The statement that leakage complaints increase when highly odorised gases such as carburetted water gas and peak oil gas are distributed is interesting. It must be kept in mind, however, that these gases are normally at maximum during winter when there are usually more accidents due to gas poisoning.

High odorosity may lead to an increase in relatively insignificant complaints, but a satisfactory balance should be maintained between reduced safety and excessive minor complaints.

Since it is possible that transmission and temperature reduction during storage may affect odour retention, it may be necessary in some cases to provide local odorising systems at the outlet of the district holder.

Satisfactory admission of T.H.T. is difficult, particularly for relatively small outputs distributed from small holder stations. To provide a level 1 lb. T.H.T. per mill. cu.ft. requires the addition of only some 45 millilitres for an hourly output of 10,000 cu.ft. I should be pleased to hear the authors' experience on the use of micro-pumps for this purpose.

Gas through soil

The section of the paper dealing with the passage of gas through soil is interesting and important. It is fortunate that our normal climate produces conditions most favourable to the retention of odour both in conventional and artificially odorised gas.

The authors are to be congratulated on the way in which they have overcome the difficulties inherent in assessing odour level. The method, although somewhat empirical, is quite reasonably repeatable and reproducible.

The use of chemical means of determination is doubtful since odour level is not an additive factor but it represents a very useful tool when interpreting odour tests.

Mr. David Beavis, Scottish Gas Board: For many years I suppose most of us, if we gave any thought at all to the smell of town gas, regarded it is as one of the few undesirable features of our fuel. It is only now, when we are turning to other methods of gas manufacture, that we begin fully to appreciate its importance. Not only that, but for the first time we also appreciate the fortuitous but happy circumstances that our principal methods of production in the past, namely, carbonisation and carburetted water gas manufacture, yielded gases with an odorosity in the very narrow band of acceptable limits set by the authors, viz., 0.8 to 3.0 $\times$ 10^4.

The presence in my Division (Edinburgh and South-East) of one of the few minor natural gas finds in the country has prompted me to take a particular interest in the work which is the subject of the present paper. On that slender experience, and conscious that almost all that we know in Edinburgh about the subject has been derived from the authors, I would venture to make the following observations.

Subjective

Having regard to the very narrow limits of odorosity set by the authors—indeed, in Edinburgh we would set them even more closely say 1.5 to 2.5 $\times$ 10^4—it is most unfortunate that, despite the authors' ingenuity, the measurement of odorosity is by a subjective method. The authors point out that four experienced observers (and they are not easily found) were subject to a variation of $\pm$ 30% about the mean on 10 out of 13 days. On the other three days the variation for individual observers was even greater. Taking a mean value of 2 $\times$ 10^4 as the desirable figure, the limits of accuracy from these observers, excluding the exceptional results, are from 1.4 to 2.6 $\times$ 10^4. The former we would regard as the minimum satisfactory odour level, particularly with high carbon monoxide coal gas from Scottish coals in vertical retorts. On the other hand, at a level of 2.6 $\times$ 10^4 and above we would agree entirely with the observations of the authors that complaints of a minor and insignificant nature will rise rapidly. There is therefore a pressing need for a more accurate method of odour measurement if odorisation is to be controlled effectively and without unhappy consequences on the district from time to time.

Our practical experience of bringing in odorised natural gas from the Cousland Well and mixing with the vertical retort gas from the Musselburgh works confirms the very important statement made by the authors on p. 20 that:

> 'When a gas originally having no odour but odorised with T.H.T. is mixed with conventional town gas of the same odorosity, the odorisity of the mixture will be less than either component.'

This is exactly what is happening at Musselburgh. The odorised gas from Cousland comes in at much the same level of odour as the locally-produced gas. The natural gas is much the lesser component in the mixture and the odour of the mixture is the same as we would expect if the natural gas had not been odorised. It has therefore proved necessary to install odorising plant at Musselburgh to increase the odour level of the mixture.

Although probably outside the scope of the present paper, our experiences with a bypass pick-up of odorant on a relatively small flow have not been too satisfactory, despite great care to avoid temperature fluctuations in gas and odorant.

The reason is clear enough from the data on vapour pressure given but experimenters in the field would be well advised to have temperature control very much in mind when adopting bypass pick-up methods for the introduction of T.H.T. Fortunately where larger flows are involved positive means of addition are possible relating accurately the amount injected to the volume of gas flowing. This means is to be commended wherever possible.

I think that the authors have found the right odorant; I hope from their future work they will give us a better means of odour measurement for control purposes.

Mr. D. L. Copp: The author has asked me to take part in the discussion because I have had a good deal to do with the original introduction of odour into gas in this country. Odour is a fairly novel topic for this Institution. My interest in the matter started in 1953, when there was a flood of sea water over Canvey Island. I was very worried, because I realised that corrosion would be accelerated a great deal, and it was already bad in that area. I also thought, from my investigations, that the odour level was not very high on Canvey Island, and I guessed that there was a decrease from the level found to begin with, and so I went into this question of the addition of odour.

The only odour which we had at that time was mercaptan. I designed a small plant, and was very thankful indeed to have the assistance of the authors in measuring odour. We started off with a dry type by-pass odoriser, but I found that we could not run it successfully without a gas rate of about 10,000 cu.ft. an hour. We therefore went over to a wet type on the same by-pass, but it also failed. We then went to a scrubber type, and when we used this first of all with T.H.T. we had almost startling results, because the T.H.T. exceeded our most sanguine expectations.

Injection

So far as methods of putting odorant into the gas are concerned, at Romford it was injected through a little pump with a varying flow from nothing to $\frac{3}{4}$-in. The T.H.T. is injected through a $\frac{1}{16}$-in. hole into the gas stream, and there is a little steam jet where steam is admitted just above it through another $\frac{1}{16}$-in. hole. That ensures vaporisation and is very successful. It is probably the best way of injecting odorant.

Dr. J. R. Dewhurst: This is a joint contribution from myself and from **Mr. C. W. Ward,** who has carried out much of the work in our laboratories at Old Kent Road.

I must cross swords with them on a

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few matters, even if the swords are buttoned and the contest friendly. They have coined the word 'odorosity'—or did I do it myself? In any case they have taken it as sterling, whereas we suspect it to be almost counterfeit. It gives the impression that here is a definite characteristic, like density or calorific value. They have defined it precisely, or so it seems, and even quote values to three significant figures. This is misleading. The whole basis must be subjective, because someone has to do the smelling and individuals vary among themselves from day to day. Even a specific odorosity relative to, say, T.H.T. is not a solution to this problem, because some people are selectively anosmal—they can smell one odour and not another. Even without going to that extreme we have found that two of our investigators differ in this way. One will make a gas twice as odorous as a standard nitrogen—T.H.T. mixture and the other only equally odorous.

In Fig. 2 of the paper there is an example of this type of difficulty. If the top right-hand point is ignored (perhaps unjustifiably, but it might not have been obtained) the line could have been drawn at right angles to the one which the authors give. While the conception of odorosity has much to commend it, it must be used with caution. We would suggest that values should never be quoted to a greater accuracy than one significant figure, and even this may be too close in some cases.

More relevant

There is another approach to this measurement which is more clumsy and very inconvenient for development and laboratory purposes, but it is much more relevant to what we are all interested in. That is the use of a panel of observers or, even more reliably, a large number of 'average people,' not specialists. There is abundant evidence that the odorimeter operator becomes sensitised. He can detect concentrations much below those which the public recognise, and, as it is the public's recognition with which we are concerned, this is a serious drawback.

At the Old Kent Road, we have adopted a somewhat different technique. The subject is asked when he can identify 'gas.' We have coined another term, 'the threshold of recognition,' which we believe to be a less spurious species. It is the concentration in parts per 10,000 at which the subject recognises the smell of gas. It is perhaps doubly subjective, but it is what we are interested in. Incidentally, we have used parts in 10,000 to try to avoid decimals. If the authors had used ten to the power three instead of four they too could have had whole numbers and the units might have been termed 'kilopongs.' Using this concept of the 'threshold of recognition,' we have examined the sensitivity of a large number of both young and old people. For 110 persons employed by the Board, we found a value of six parts per 10,000 as the average, but many could recognise less than three parts per 10,000, and a few could not recognise the odour unless the concentration exceeded 15 parts in 10,000. In other tests, with persons under the age of 65 years, we have found one or two who cannot detect the gas at all.

With older persons the position is somewhat different and perhaps more serious. Of 60 people over the age of 65 and resident in hospitals or an institution, nearly one-quarter could not smell the normal town gas and the remainder had an average 'threshold of recognition' of about 25 parts per 10,000. However, the position is not quite so bad as this result suggests, for when we tested the members of a number of old folks' clubs we found that, while there were still 25% who could not reliably recognise the smell of normal town gas, under odorimeter conditions, the 'threshold of recognition' of the others was only slightly higher than that for the under-65's—ten parts as compared with six parts in 10,000.

It would seem from this, of course, that the present level of odorosity of town gas is probably satisfactory, but it is clear that the problem of old people in connection with the hazard of gas poisoning cannot be solved by increasing the odour of the gas. In a great many cases, old people should be supplied with safety appliances as now available or being developed, or the gas should be detoxified; but that is another problem, outside the present subject.

T.H.T. is a good odorant, and the authors are to be congratulated on the work they have carried out to establish this and to determine the likely limitations. Do not be put off by the table on p. 19 of the paper. When T.H.T. was accidentally spilled outside one old folks' club there were a great many complaints of a gas leak and, although in our tests some subjects said that odorised gas had an unusual smell, they were almost unanimous in accepting it as town gas.

The authors make brief references to room tests and dismiss the technique as being inapplicable to the type of investigation which they wished to make. We have made some tests in which hydrogen having the typical smell of coal gas, and in some cases coal gas itself, was admitted to a room in which the subject was normally occupied.

The concentration of gas was measured by sampling the air near the subject and determining the hydrogen content by means of a katharometer. This work indicated that the 'threshold of recognition' of gas under these conditions is slightly lower than the value obtained in our odorimeter, but above that which would be expected on the basis of the authors' determinations of odorosity.

There is no time to go into the reasons why our 'threshold of recognition' may not always be directly comparable with the authors' measurement of odorosity, or into the number of factors, including the purity of the air and the sensitivity of the subject, which may affect this result, but I think it is true to say that the differences are normally of a minor nature.

A trained observer with either technique will always be more sensitive than an untrained person representative of the general public, and this factor must be borne in mind. The important point is that the odorimeter technique, whether that adopted at Old Kent Road for the purpose of testing large numbers of people with a minimum of inconvenience, or that adopted at Watson House for use with the specialist, does give an indication of the concentration of gas which will probably be recognised in the event of a leak occurring in occupied premises.

Finally, I should like to mention that we have adopted the use of T.H.T. for odorising the gas produced by the Segas process at the Isle of Grain, and the results confirm the authors' findings that 1 lb. of T.H.T. per mill. cu.ft. of gas gives an odour which is similar to that of normal town gas both in strength and quality.

Mr. D. J. Turner: In Wales in 1957 the need to give attention to the odour level of gas arose in connection with the reported loss of odour at the extreme end of the western section of the South Wales grid, which had been in use since November, 1956. The main is of steel construction, internally coated with red lead. There was a full knowledge of the work going on at Watson House. It was established that the odour intensity was reduced to one-quarter during the course of distribution, and therefore the red lead coating may play a part in the deodorisation of the gas, perhaps by a conflicting odour. Checks on the odour level are now made at intervals. In the case of stripped gas, an odorisity of 1.2 would appear high compared with our experience.

All-important

From the safety point of view, the all-important factor is the relation between carbon monoxide content and general odour level. We have in Wales reduced the carbon monoxide content during eight years from an average of 11.2 to 7.3 for the gas distributed.

Mr. G. T. Pickering: I should like to report briefly on the trials which we have made, so far as they have gone. For six months we have used the by-pass vaporiser, which I agree is not very satisfactory. We started first to odorise gas having an odour level of 0.9 to 1.3 close to the works, supplied to a very large building with some hundreds of people in it. We got up to something like 2 lb. per mill. cu.ft., but nobody noticed any difference in the odour. We then went on to a small isolated district, and have worked up to an average of 1½ lb. per mill. cu.ft., and we know that at certain times the rate has mounted to 2 lb. or more. We have not had any reaction at all from the consumers, nor do complaints appear to have increased. The gas had an odour level—I will not use 'odorisity'—of 1.0, and we have increased it to 1.6.

We want to increase the safety of gas, particularly for old people. It looks as though we should go to 2 lb. per mill. cu.ft. Bearing in mind the limited sense of smell of old people, and the cost of odorising the gas, we shall have to do some hard thinking to decide whether or not to spend the money in some way more directly applicable to old people.